Simulating the Past?

Juan A. Barcelo

UNIVERSITAT AUTONOMA DE BARCELONA

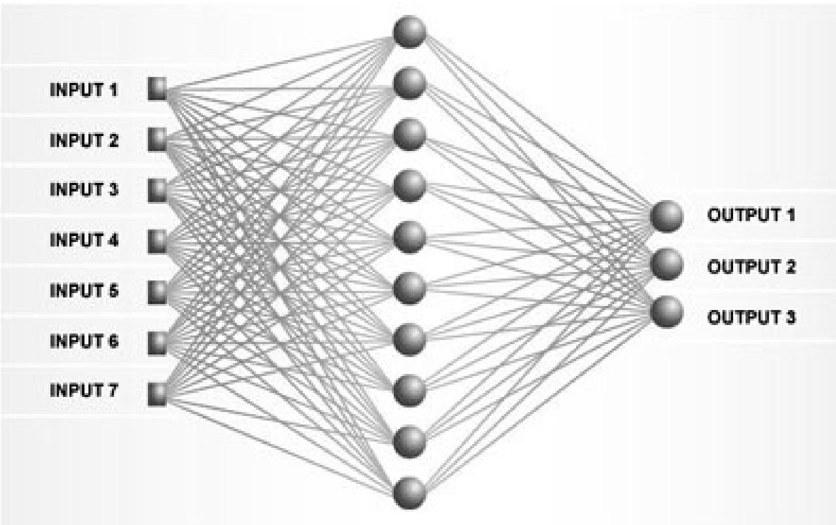
Explaining

why archaeological observables are like they are?

Shape
Size
Texture
Substance
Materiality
Mechanical properties

Simulating

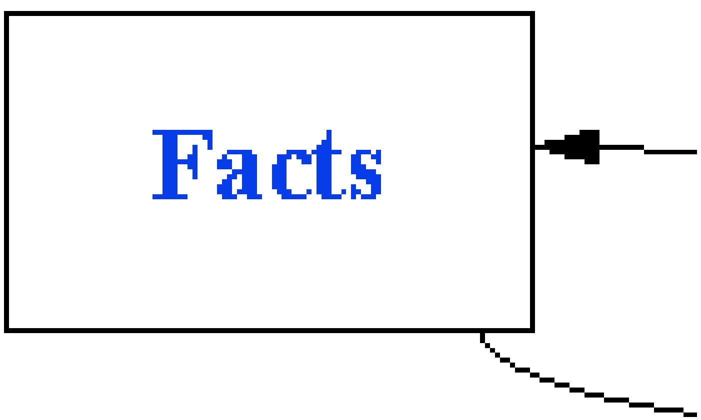
how archaeological observables are like they are



We build a “model” of the causal mechanism associating

human activity-physics-observable properties

Inducction-Archaeological Experimentation



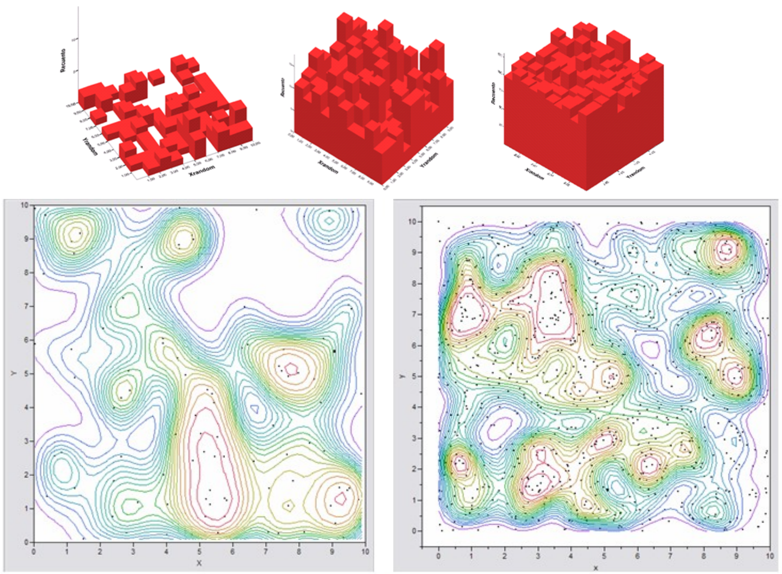
Explaining

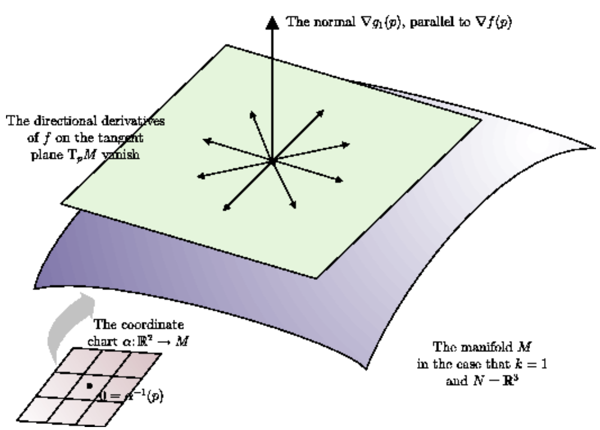
why archaeological observables are where they are?

Position
Space
Time

Simulating

how archaeological observables are where they are



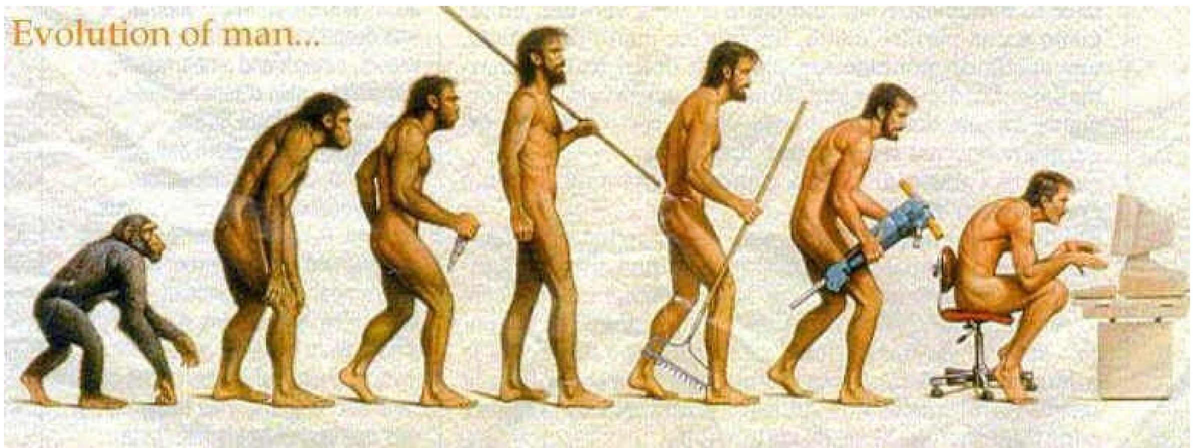


We build a “model” of the causal mechanism associating

human activity-accumulation-spatiotemporal variation

Inducction-Statistical Modeling-Prediction

Explaining
why human society changed yesterday, changes now and it will change tomorrow



- The change from Animality to Humanity
- The origins of Cultural Diversity and Ethnogenesis
- The Origins of Social Inequality
- The Origins of Agriculture
- The origins of the State
- The Origins of Capital Accumulation

Explaining

why human society changed yesterday, changes now and it will change tomorrow

Explaining

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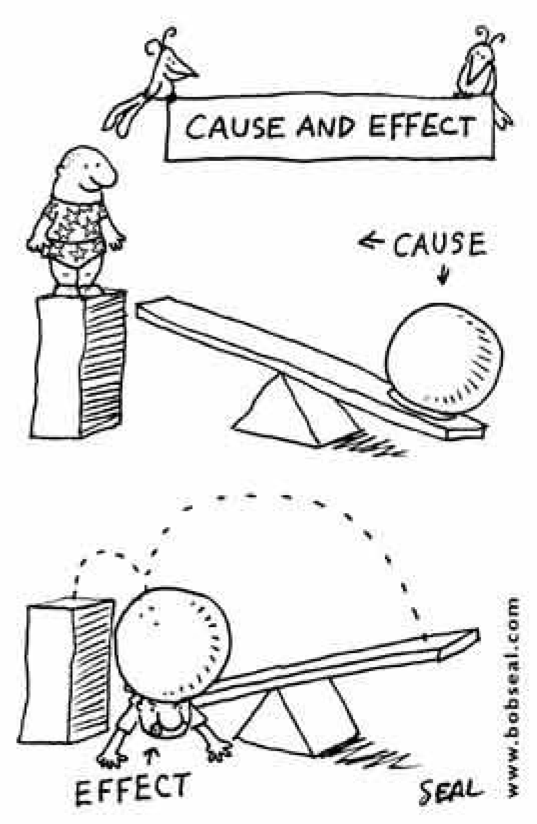
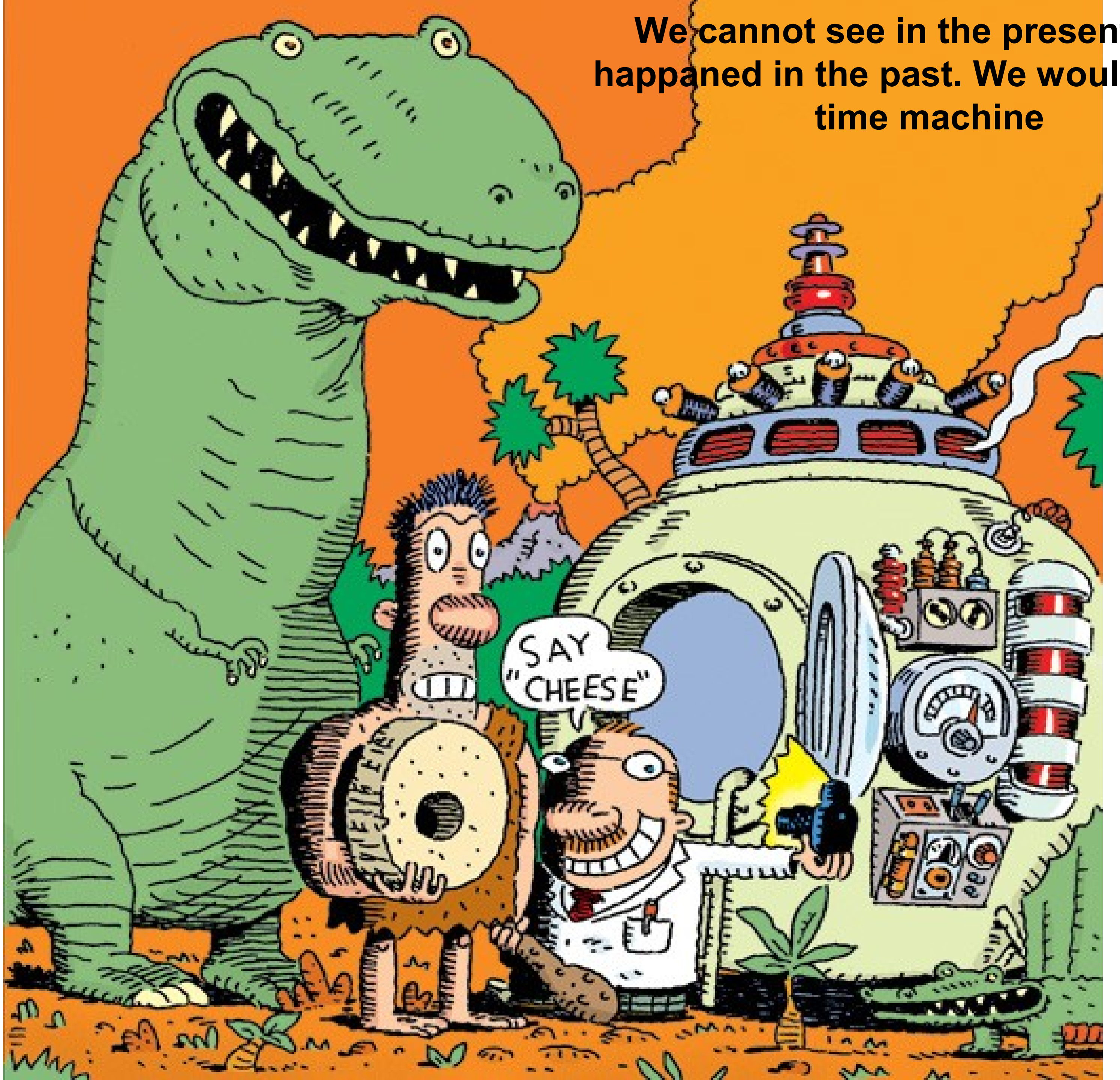
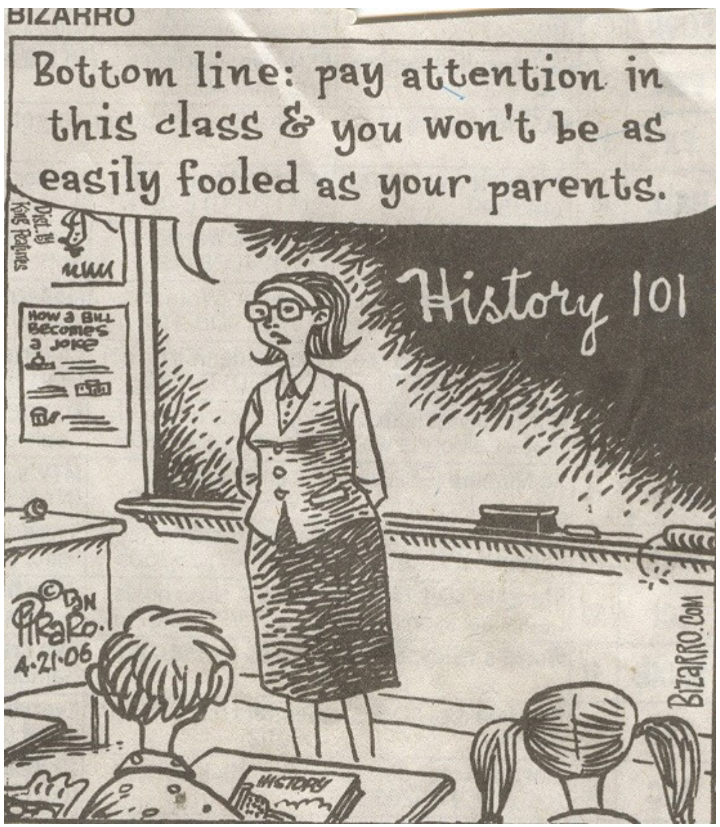


Historians explain past social events by showing how their results and consequences fit into a causal structure, that is to say, a vast network of interacting actions and entities, where a change in a property of an entity dialectically produces a change in a property of another entity (transformation).

We cannot see in the present what happaned in the past. We would need a time machine



Explaining
why human society changed yesterday, changes now and it will change tomorrow



There is no way of actually going back into the past to test a historical hypothesis.

Explaining

why human society changed yesterday, changes now and it will change tomorrow

If we cannot enter into the past that once existed, we can enter into a virtual past that we have created artificially according to what we know for certain about such past

Simulating

how human society changed yesterday,
changes now and
it will change tomorrow

WBD 2010 illustrations © Joe Berger

Historians seem to be placed in a virtual world extracted from a narrative, assumed true, written by an individual who saw someone doing something in the past

Simulating

how human society changed yesterday, changes now and it will change tomorrow

Such virtual worlds are expressed narratively, using verbal language

Simulating

how human society changed yesterday, changes now and it will change tomorrow

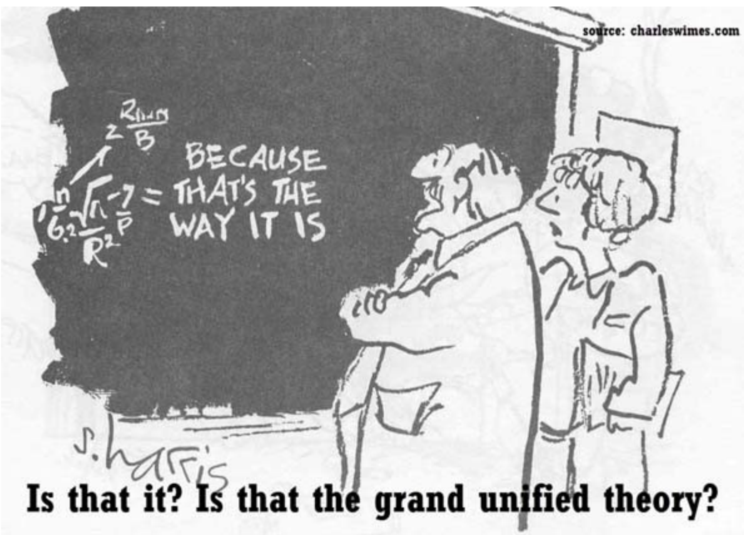
"IT'S REAL. HERE IS A LETTER OF AUTHENTICITY."

In archaeology we do not have past witnesses, nor any narrative to build our own “virtual” worlds.

Is Archaeology an “impossible” discipline beyond what ancient materials can suggest from their material properties?

Simulating

how human society changed yesterday, changes now and it will change tomorrow



It has been suggested that Human Nature has not changed from the past to the present.
Is it then possible to understand the past from what we know human behavior and mentality?

This perspective is full of unprovable apriorisms

Simulating

how human society changed yesterday, changes now and it will change tomorrow

Learning by Doing:
Can we build an “artificial” past?

Let us consider this possibility:

Simulating

how human society changed yesterday, changes now and it will change tomorrow

Take 1000, better 2000 humans.
The same quantity of men and women.
The same quantity of tall and short, clever and dull

Simulating

how human society changed yesterday, changes now and it will change tomorrow

Take them all modern technology (specially smartphones!) and let them build a prehistoric village, and reproduce the same activities in the same way as our ancestors

Simulating

how human society changed yesterday, changes now and it will change tomorrow

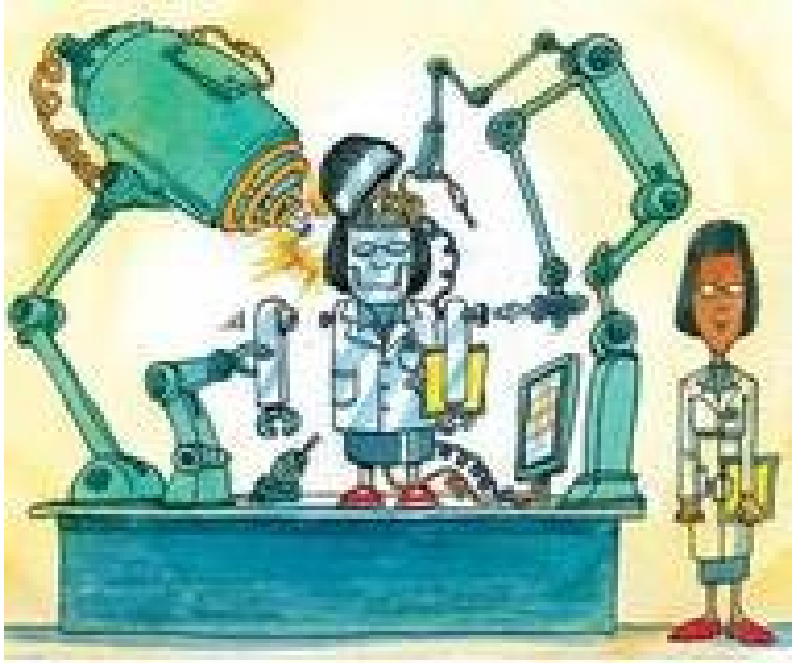
"You've successfully completed the transaction to sell your soul. A digital receipt will be e-mailed to you."

And now the most difficult thing: all of them must sign a contract so their children only learn the current technology at the village and nothing from our present.

And repeat this contract for the children of their children for the next 4000 years, in order to observe changes and transformations.

Simulating

how human society changed yesterday, changes now and it will change tomorrow



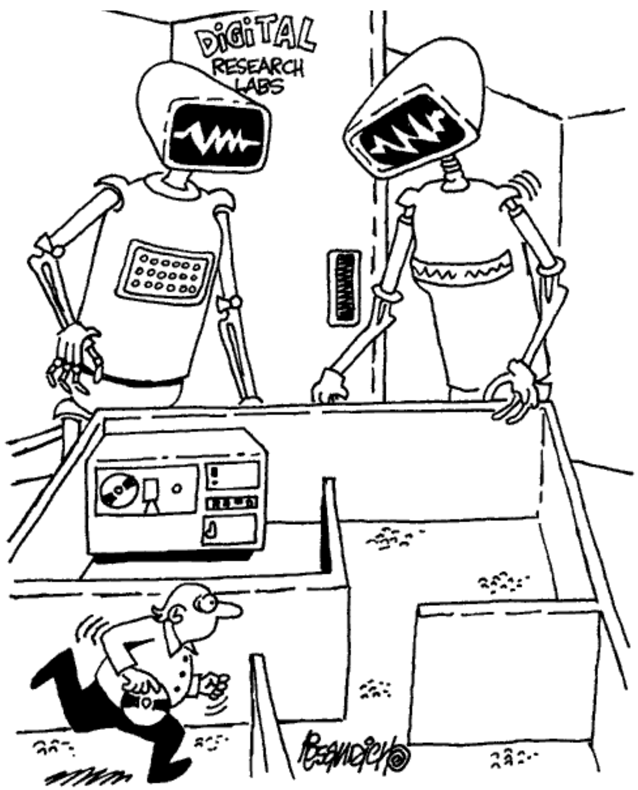
Is this as “impossible” as it seems?

Instead of people, let us program “virtual People”
Instead of a prehistoric village, let us build a virtual village

Instead of human labour and behavior, let us write some algorithmic functions

Simulating

how human society changed yesterday, changes now and it will change tomorrow



And let "virtual agents" live in a virtual environment and observe how everything evolves and changes as time pass

“Virtual” means ....

A reference to a “model”,

a replication

The idea of something acting as a surrogate

The idea is to be able to“understand” the past because we have “recreated” it inside the computer

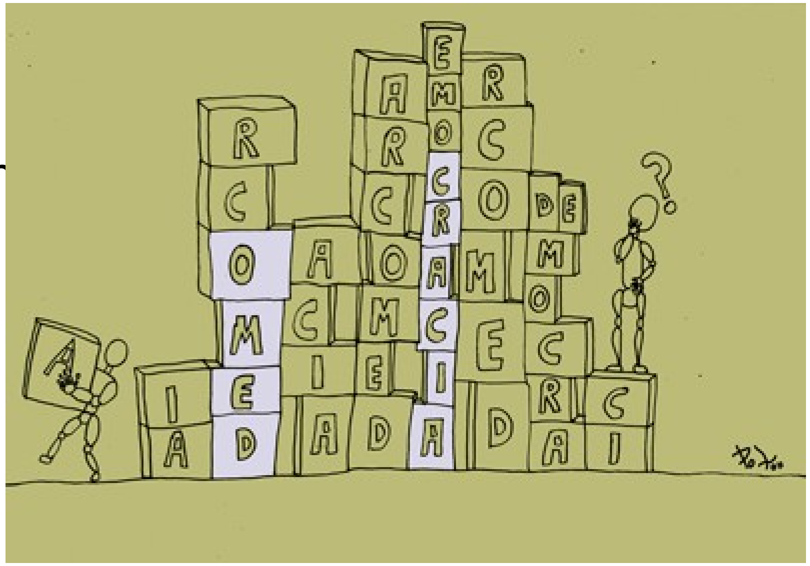
What is a model?

- A representation of some (not necessary all) the elements of an entity
- The aim of the model is to allow the understanding of the entity's structure or behavior.
- It allows to "experiment" with a surrogate of that entity, modifying it according to the intended final goals

Simulating Human Society

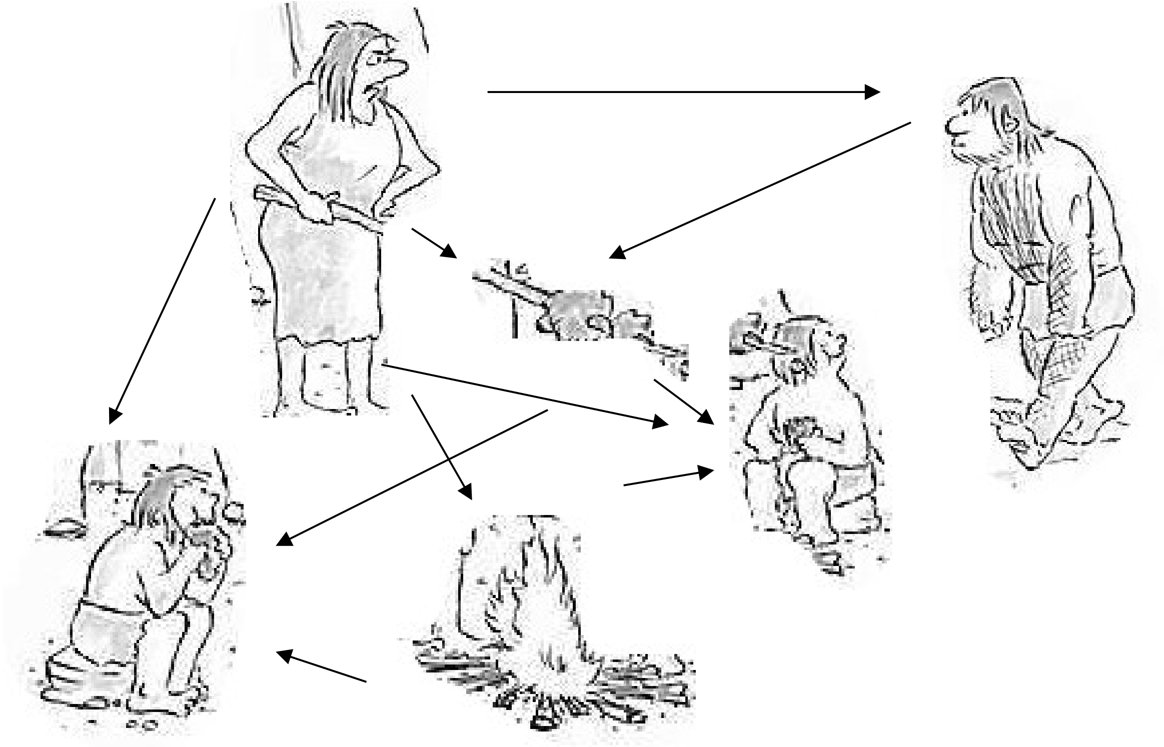
According to this perspective, the building blocks for explanations in the social domain are

- **products** (people, goods, information
- **production** (human labor, social action), and
- **events** (the context in which production took place)



organized such that they are productive of some changes – regular or irregular- from start-up to finish or termination conditions

Agent Based Modeling.



Everything is an “agent”

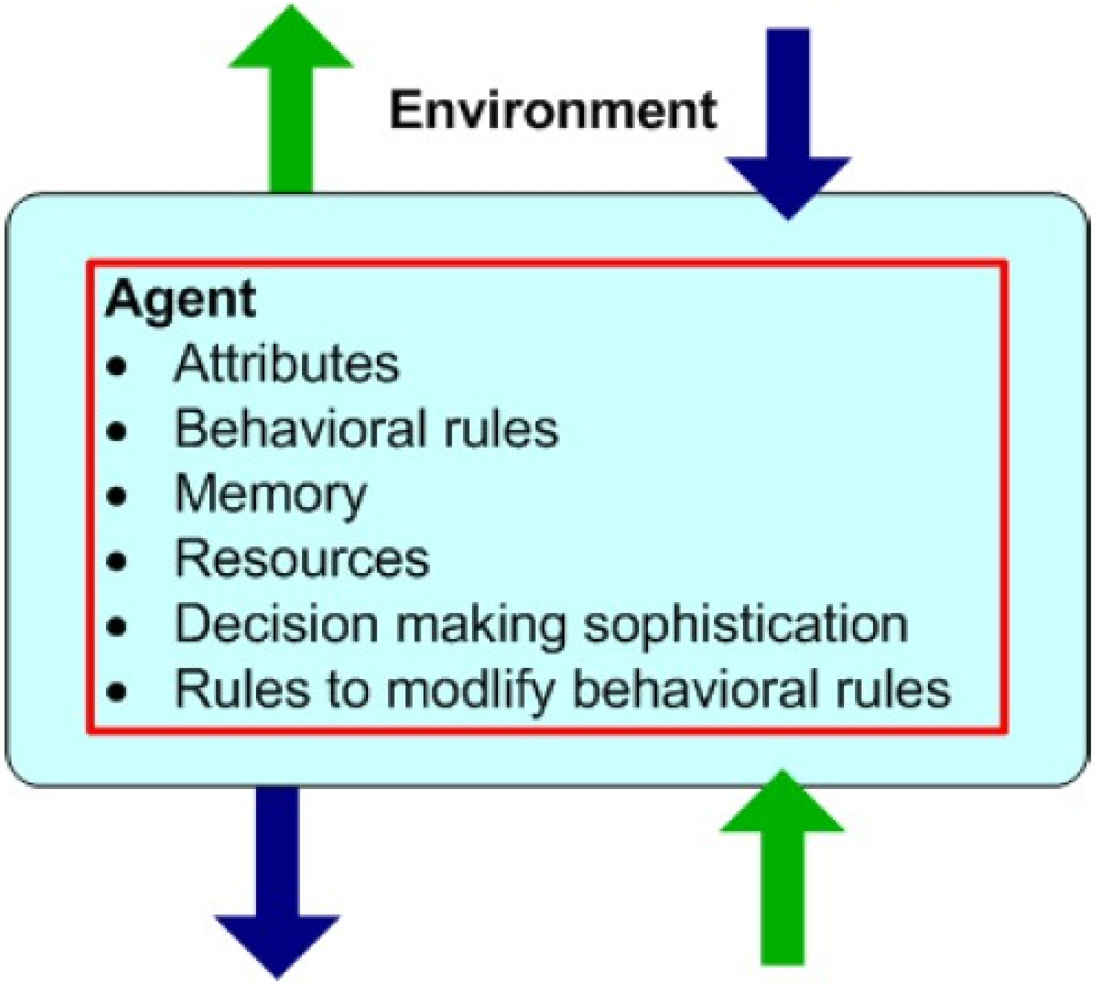
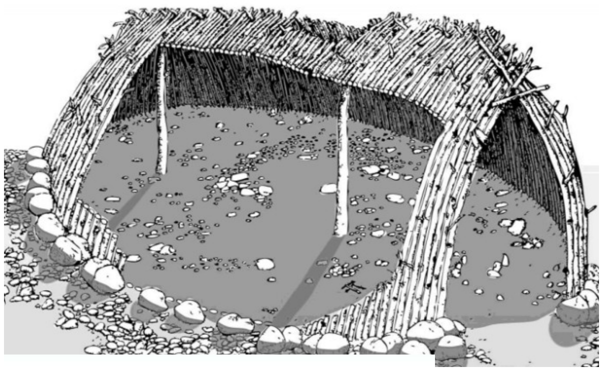


Figure 1: A typical agent

Agents -> Things / Tools



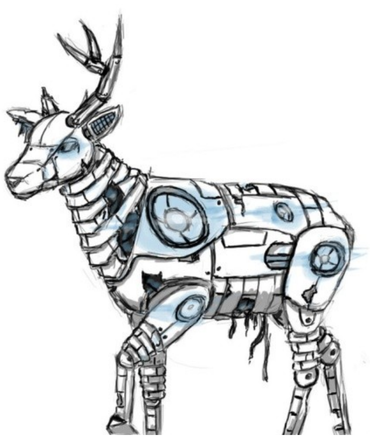
An agent simulating a thing is just some computer code with specific attributes:

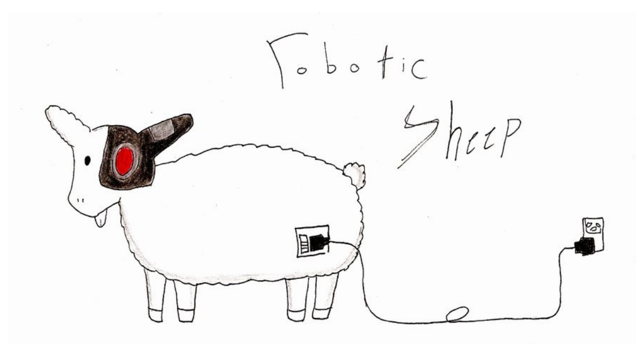
Size
Shape
Texture
Substance
Mechanical properties

Agents -> Animals

An agent simulating an animal is just some computer code with specific attributes:

Size
Sex
Taxon
Ethology
Biomass



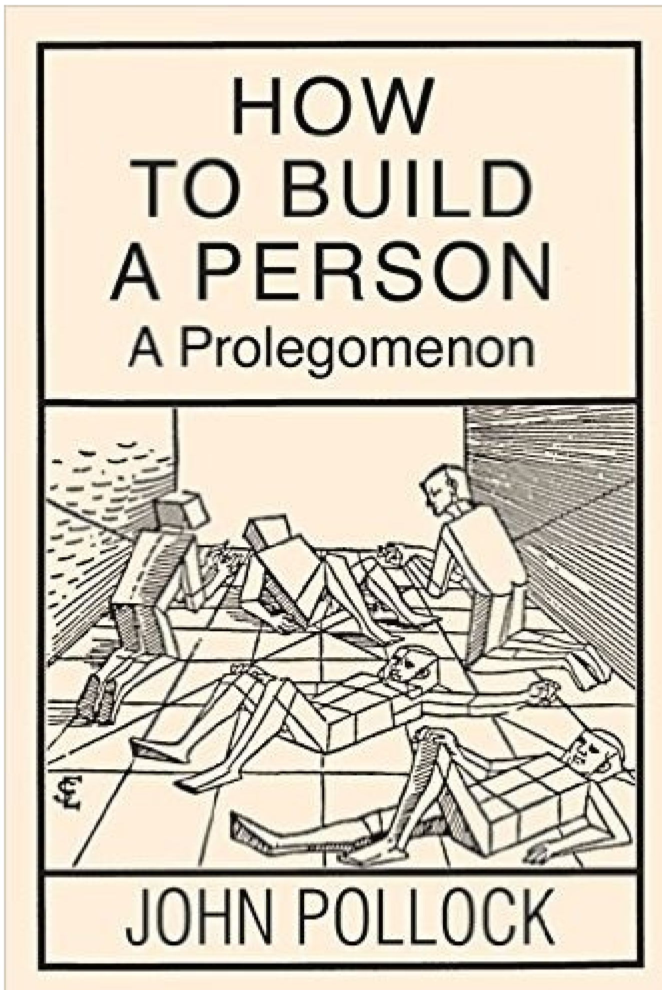


Agents -> Persons

An agent simulating a person is just some computer code with specific attributes:

Age
Sex
Energy needs
Acquired Energy
Culture
Knowledge
Ethics Values
Goals
Plans

Agents-> Persons

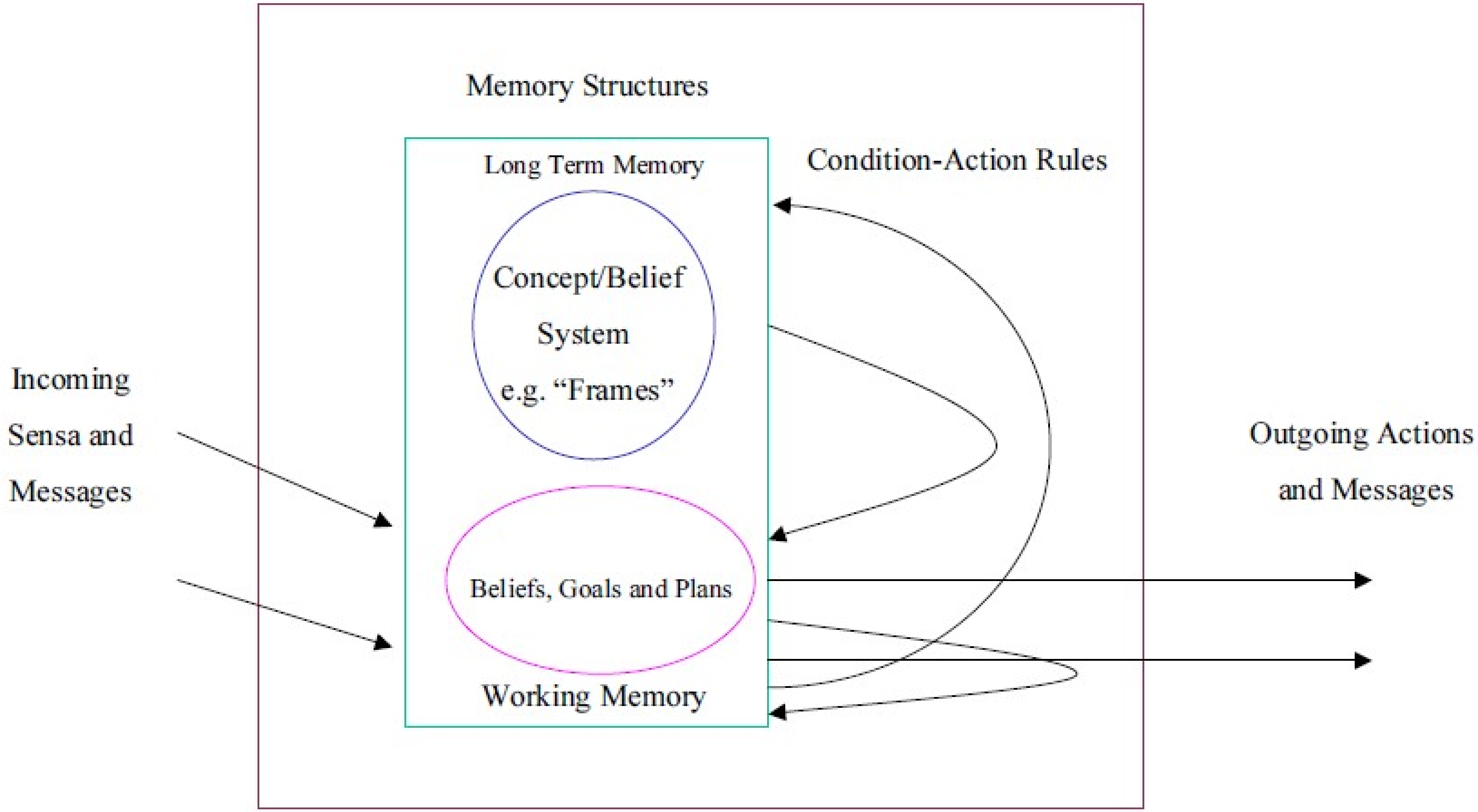


The idea of reproducing people inside a computer is not very popular, nor it is well accepted, even at scientific domains.

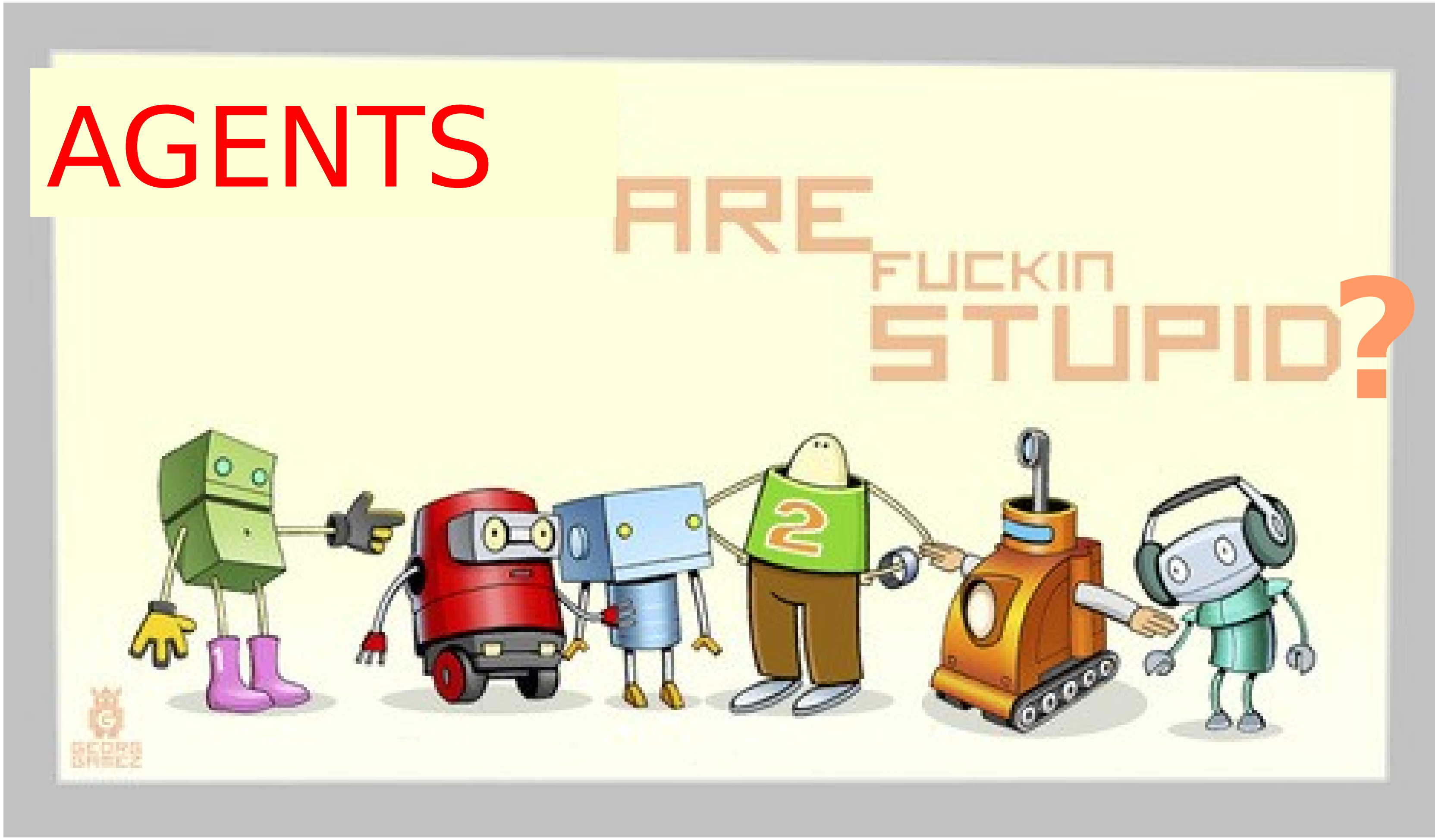
Do you play with people?
Are you trying to predict the future?

We are real people, and not robots!

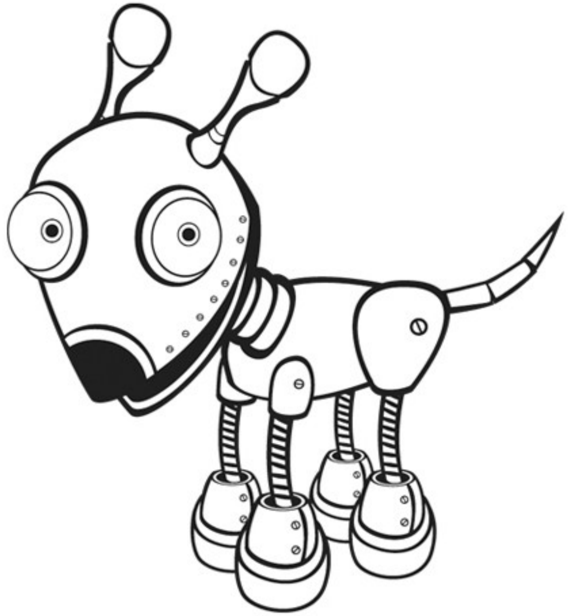
An Agent Architecture



AGENTS

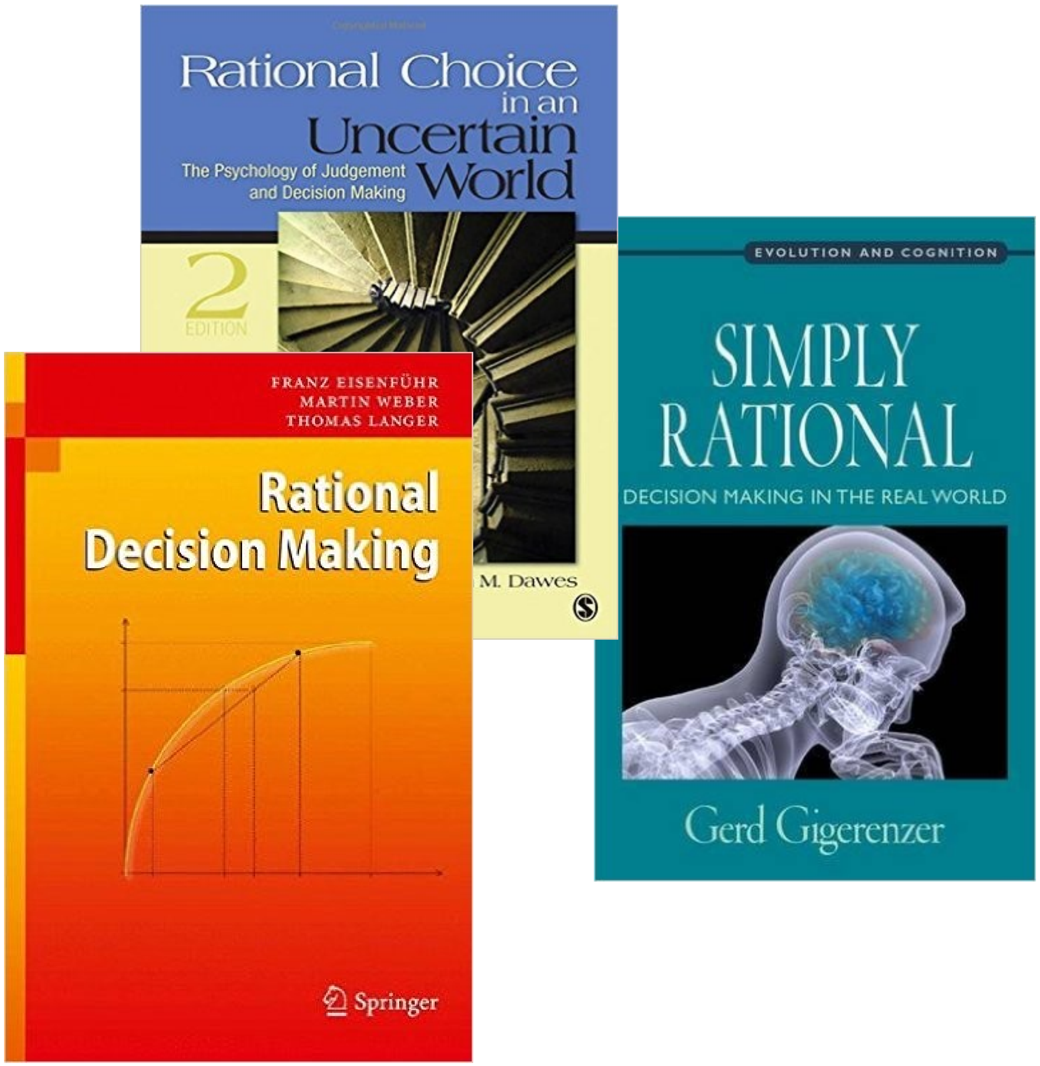


REACTIVE AGENTS



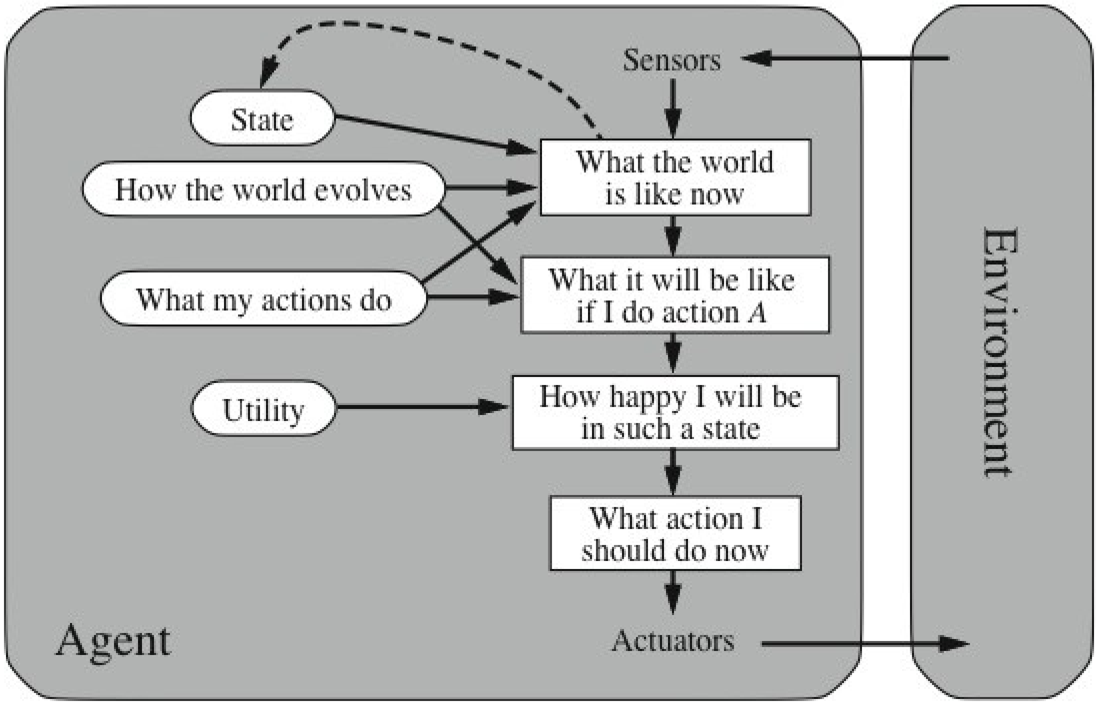
DELIBERATIVE AGENTS

SIMULATING HUMAN DECISIONS



Optimization
Game Theory
Probability Theory
Fuzzy Logic
Heuristics

SIMULATING HUMAN DECISIONS



Optimization

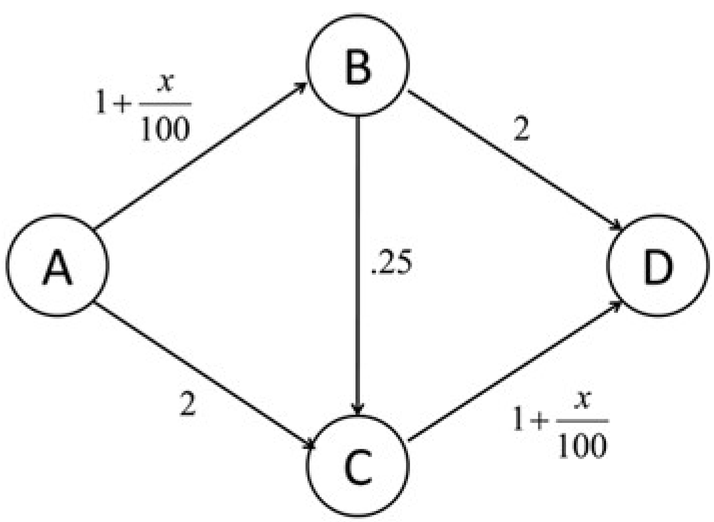
To be rational, any decision should imply a way to evaluate the advantages or drawbacks of each decision. This is implemented in terms of *utilities* to be maximized.

$$\begin{array}{ll} \underset{x}{\text{minimize}} & f_0(x) \\ \text{subject to} & f_i(x) \leq b_i, \ i = 1, \ldots, m. \end{array}$$

SIMULATING HUMAN DECISIONS

	Player 2 adopts strategy A	Player 2 adopts strategy B
Player 1 adopts strategy A	*4 / 4*	*1 / 3*
Player 1 adopts strategy B	*3 / 1*	*2 / 2*

A sample coordination game showing relative payoff for player 1 / player 2 with each combination

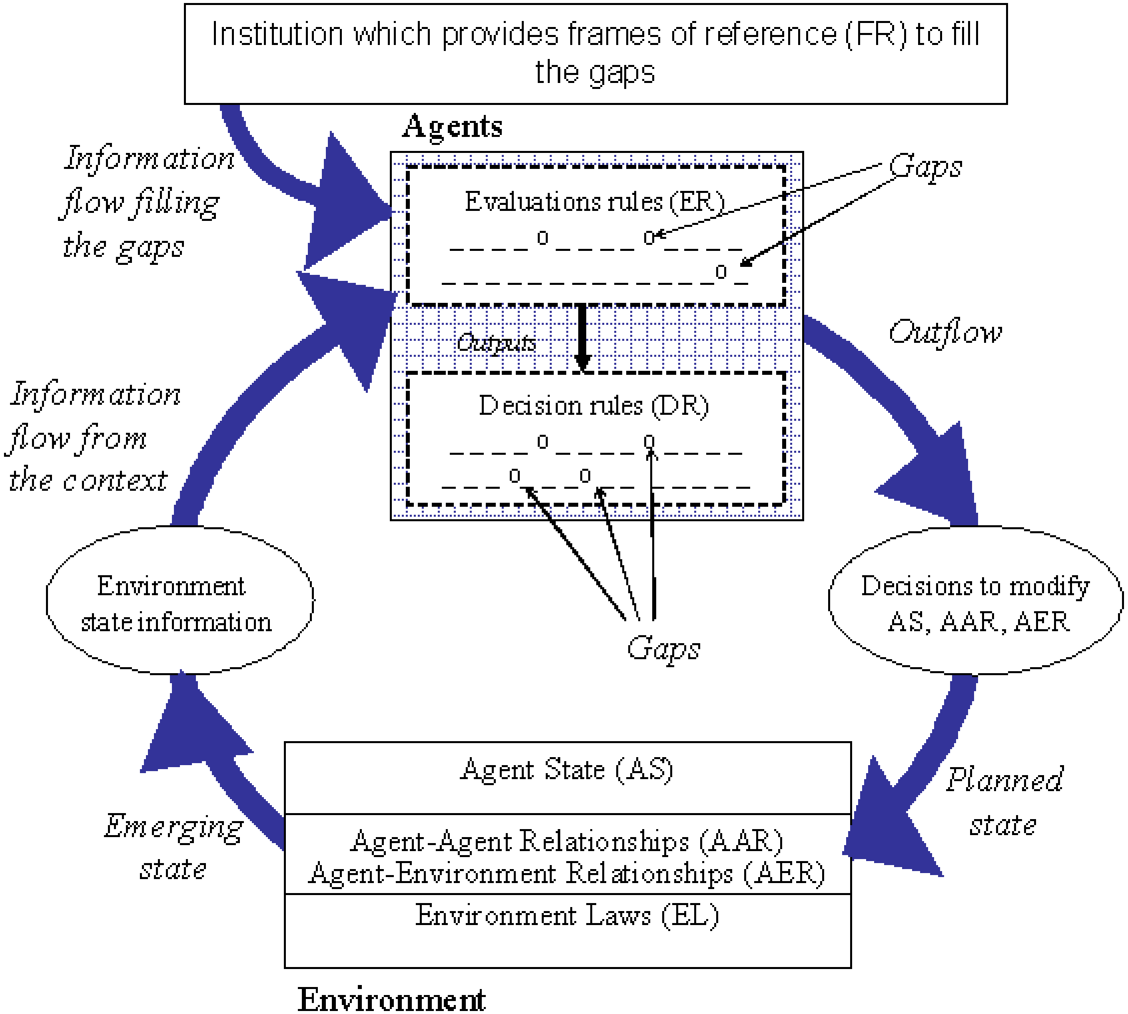


Optimization

It is implemented in form of Game Theory.

In game theory, the **Nash equilibrium** is a solution concept of a non-cooperative game involving two or more players, in which each player is assumed to know the equilibrium strategies of the other players, and no player has anything to gain by changing only their own strategy. If each player has chosen a strategy and no player can benefit by changing strategies while the other players keep theirs unchanged, then the current set of strategy choices and the corresponding payoffs constitutes a Nash equilibrium

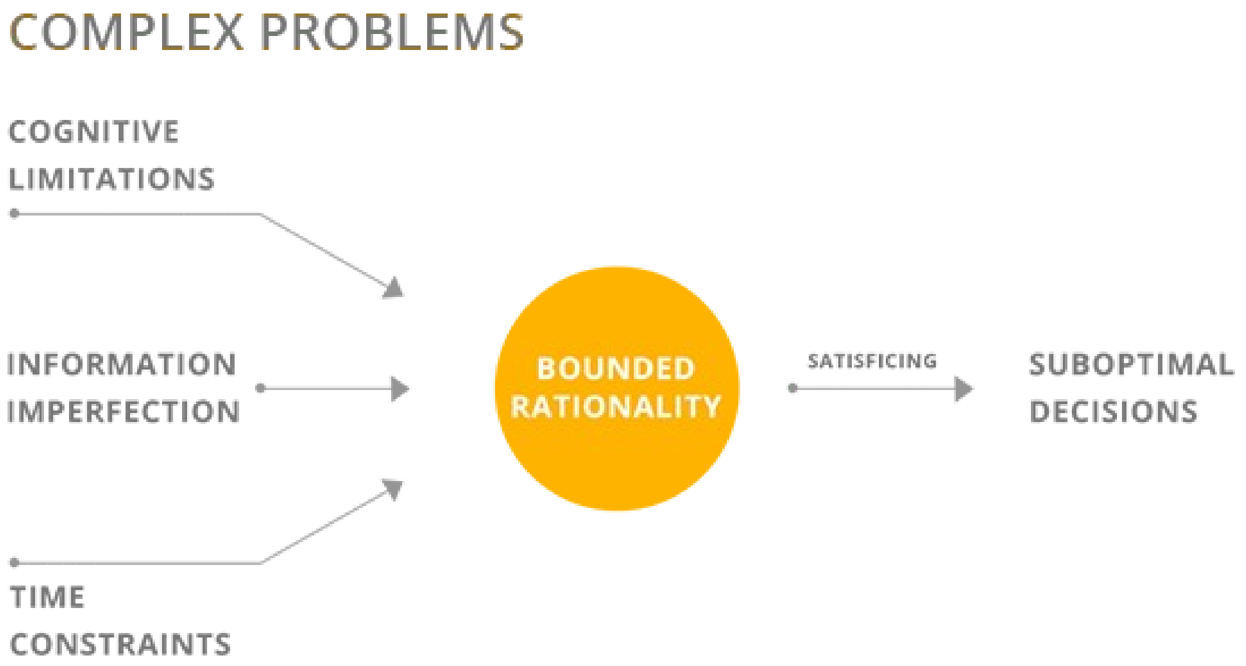
SIMULATING HUMAN DECISIONS



Optimization

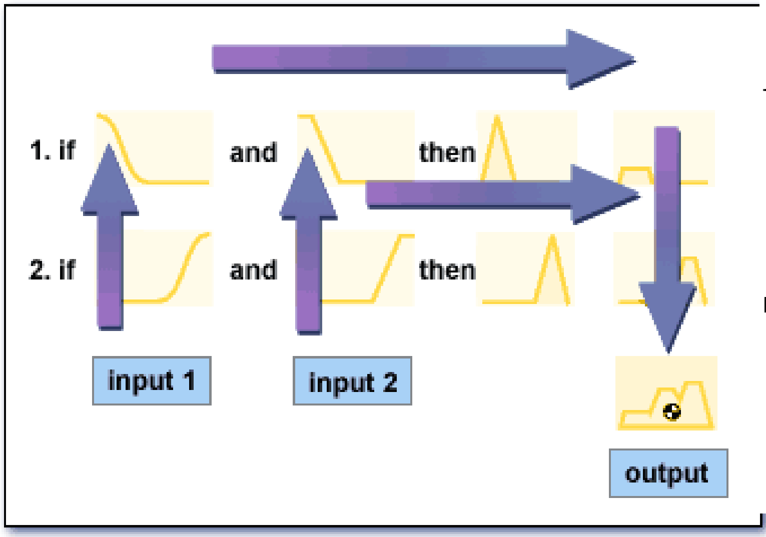
To be rational and be capabe of maximizing or minimizing utilities, an agent should learn the evolving environment of landscape features and actions performed by other agents in the neighborhood

SIMULATING HUMAN DECISIONS

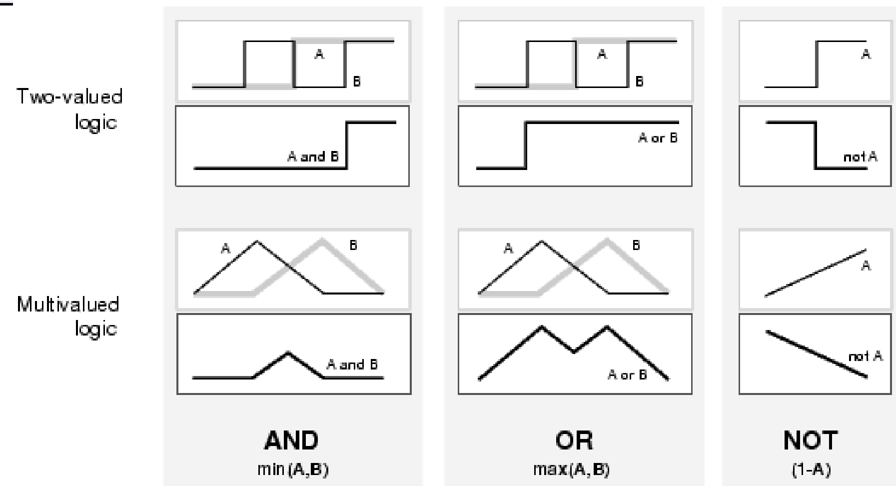


Incomplete Information

SIMULATING HUMAN DECISIONS

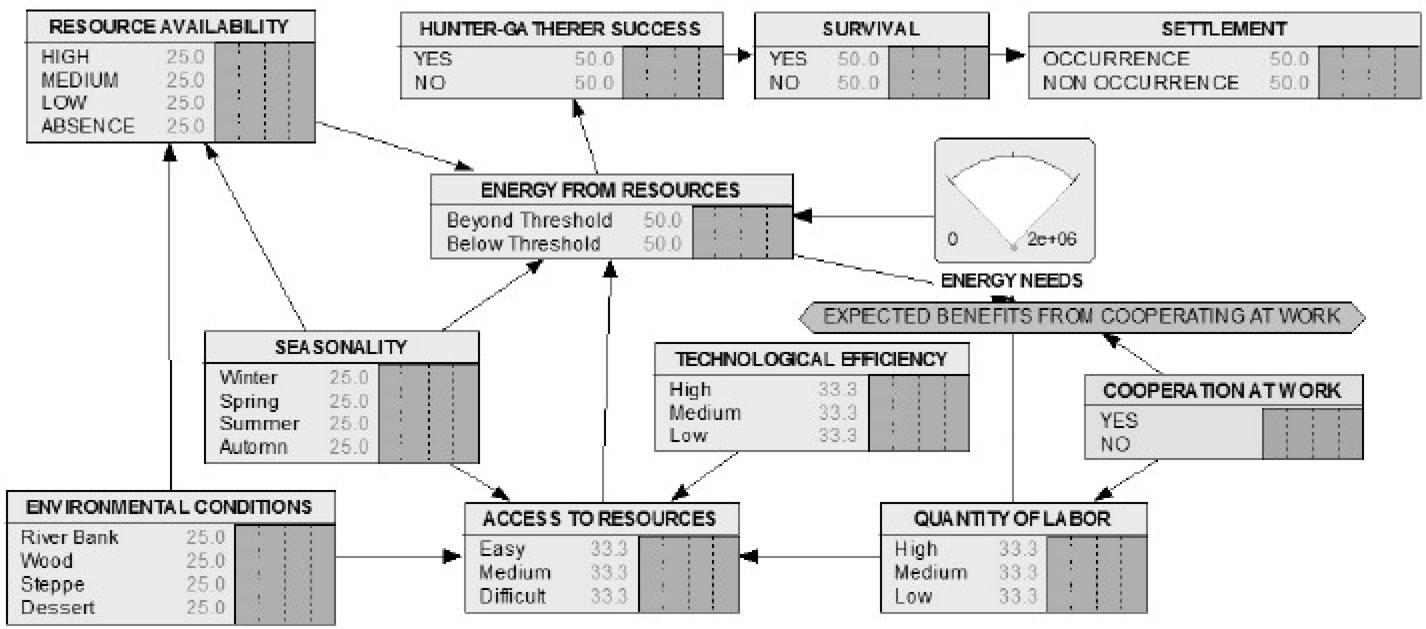


Interpreting the Fuzzy Inference Diagram



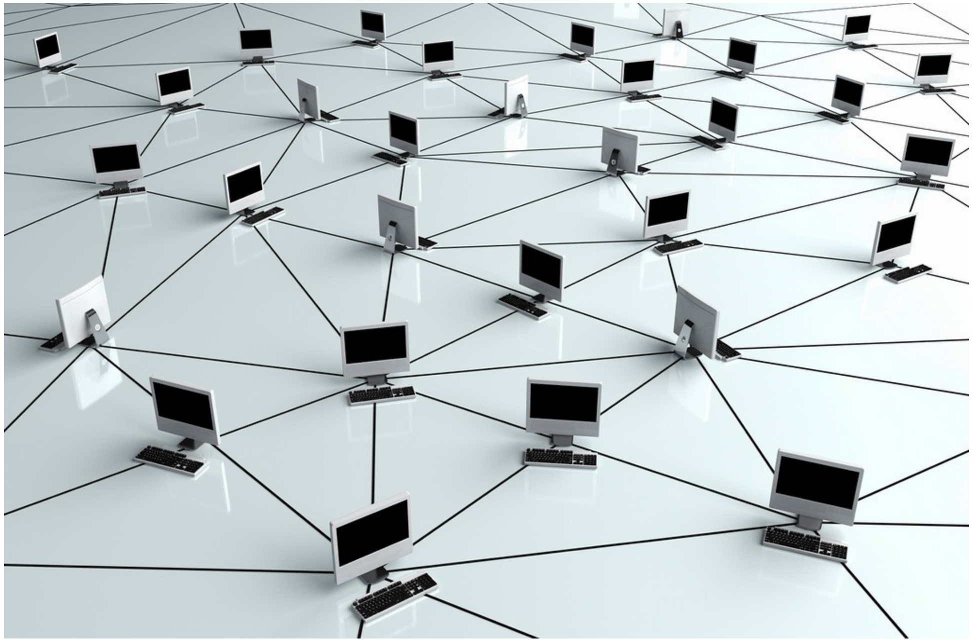
Fuzzy Logic to implement
Bounded rationality mechanisms

SIMULATING HUMAN DECISIONS



Beyond the individual level, accumulated decisions can be explored probabilistically

And Agent Based Models are systems ef connexted expert systems

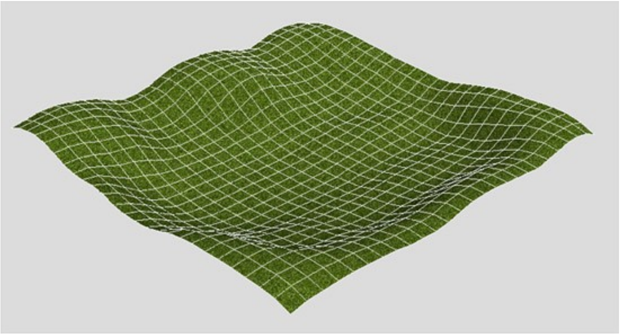


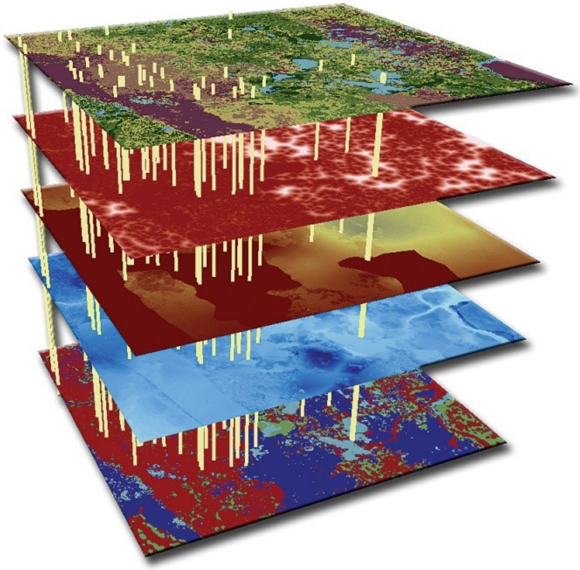
Agents -> Sets of Persons

Because in Archaeology the
Individual agent is usually invisible, it
Is very common to program an “artificial
Society” at the level of
HOUSEHOLD (family)
LOCAL GROUP (Settlement)
NATION

Attribute set is then different.

Virtual Agents in a Virtual Environment

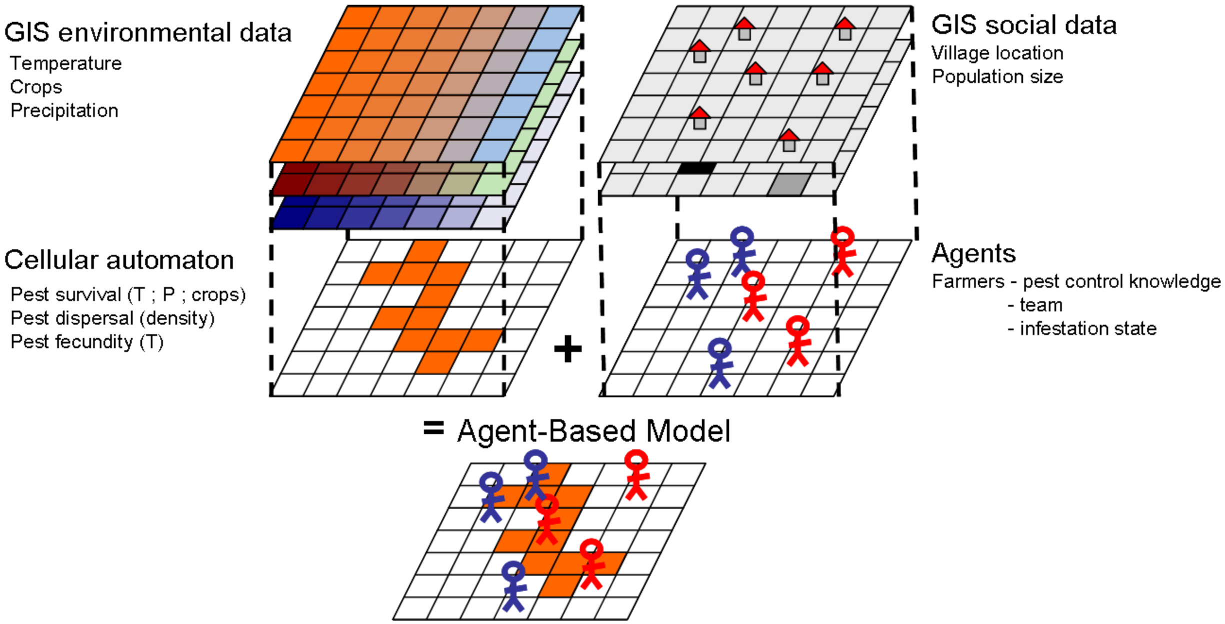




This is the easiest part,
Because we can integrate GIS
Models into an ABM.

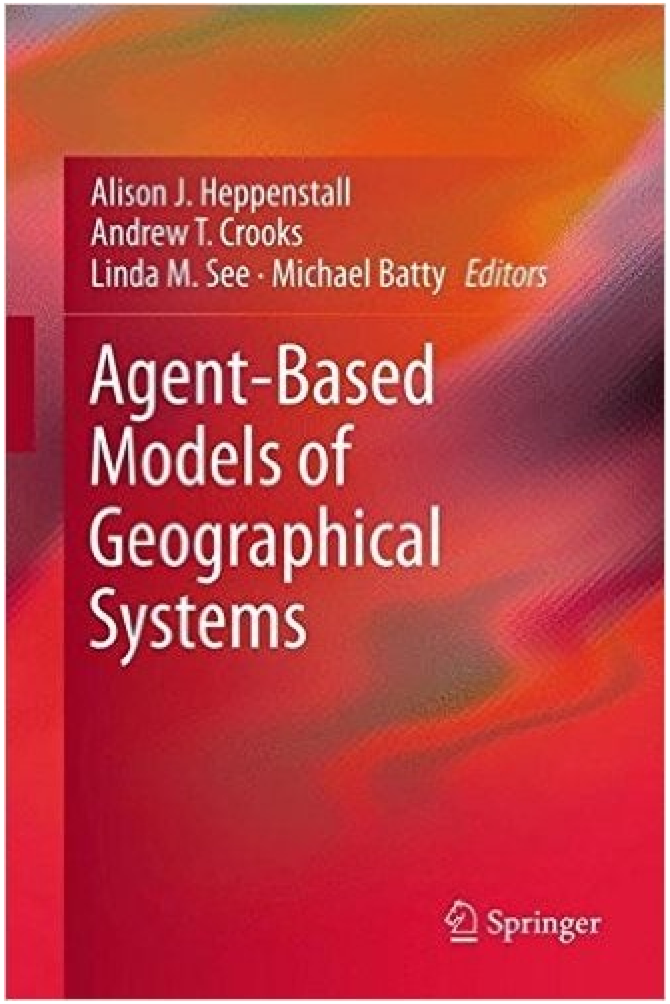
You can use a vectorial
Geographical database
Or a raster-based GIS
(more usual)

Virtual Agents in a Virtual Environment



Virtual Environments are usually divided into “patches”, that is homogenous Areas with the same quantity of resources, vegetation, or geographical features

Virtual Agents in a Virtual Environment



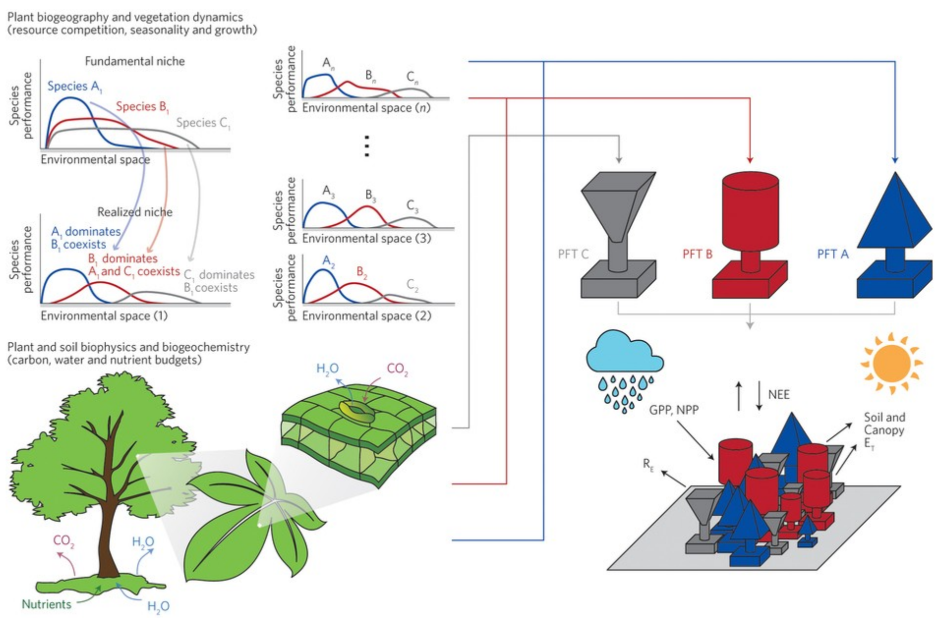
It is up to you to decide to
Program the Environment
As a particular entity with values (GIS)
Or as a series of agents:

For instance:
GIS: Number of Deer (Attribute Patch)
Deers are Agents within the system

Agent Based Dynamics

- **An agent is 'alive' in its environment**. An agent has direct interactions with its world.
- The agent may act on the environment, which in turn provides perceptions to the agent.
- **The complexity** of these interactions **is primarily constructed in the agent**, and not in the environment. An agent observes and interprets the world. The environment may change, but the agent will have to observe these changes.

Agent Based Dynamics-> Environment

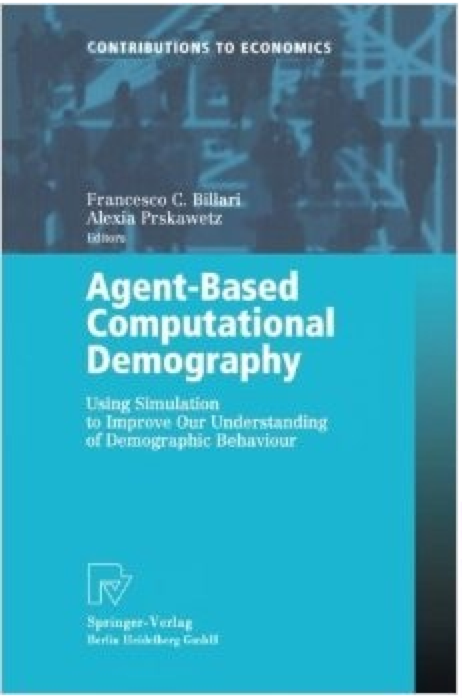


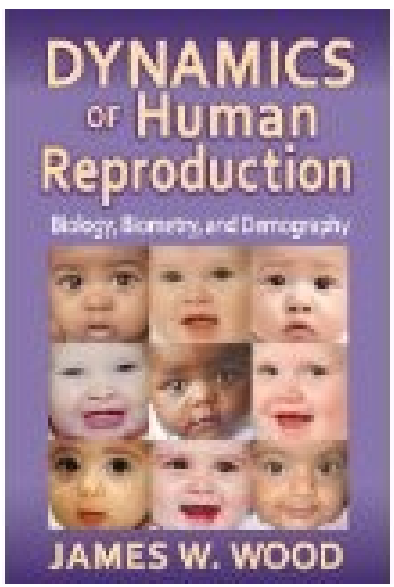
You should introduce "natural" dynamics:

- clima
- pluviosity
- natural reproduction
- Natural catastrophes

To build the "environmental engine", you use paleoecological data and ecological mechanisms

Agent Based Dynamics-> People



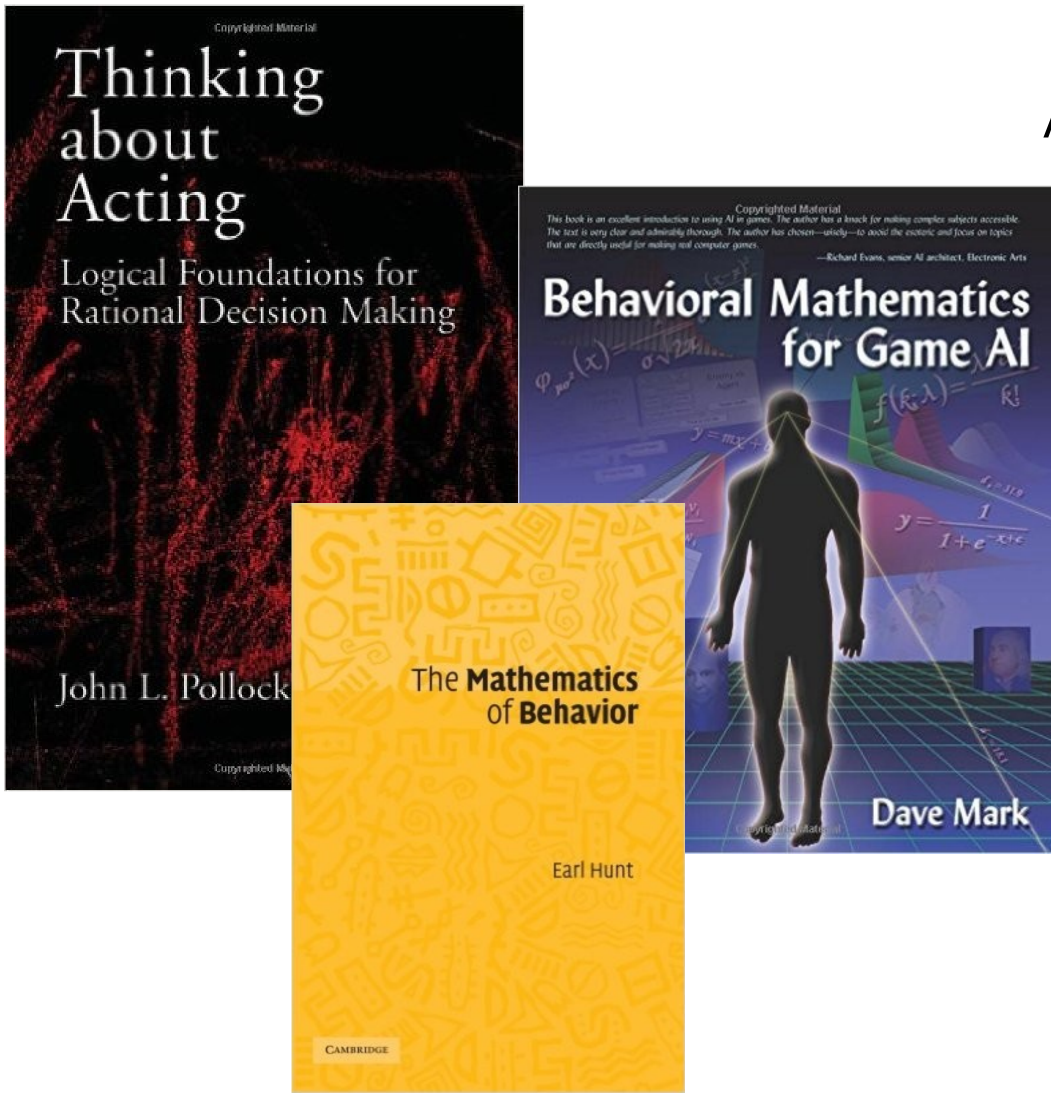


DEMOGRAPHY:
Demographical mechanisms are relatively
Well known.

We should program how agents die
and new agents born, and how the
number of living agents evolves.

This is not just biological reproduction.
We can introduce social norms to
constrain human reproduction

Agent Based Dynamics-> People



Agents behave:

- move
- hunt
- gather vegetables
- produce subsistence
- share
- interact
- kill
- die

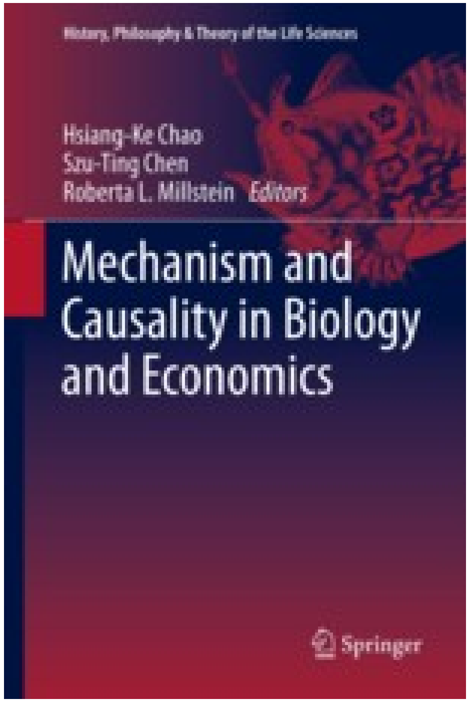
Coding “Human action”

```
to move
  ask families [
       set-neighborhood-and-group
       move-to one-of my-neighborhood
       set heading random 360 fd 0.5 ]
  ;if movement-rule = "follow local leader"
  ;[  ask families [
  ;    set-neighborhood-and-group
  ;    set leader one-of (turtle-set self my-group) with-max
[capacity]
  ;    move-to one-of [my-neighborhood] of leader ]
  ;]
End
```

What is a “Social Mechanism”

Mechanisms

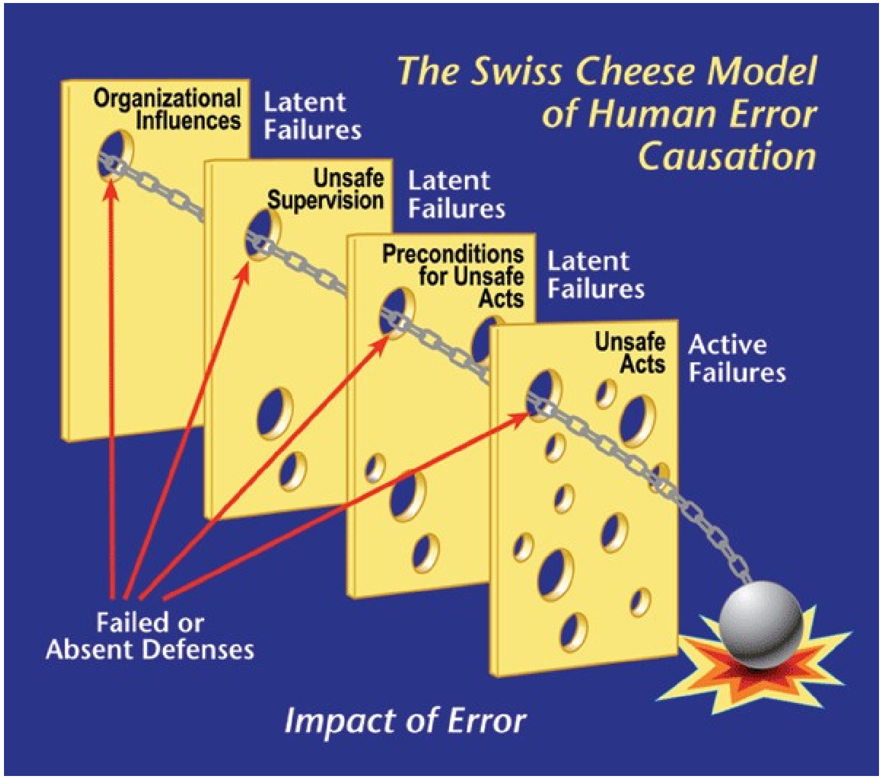
are entities and activities organized such that they are productive of regular changes from start or set-up to finish or termination conditions



What is a "Social Mechanism"

Obviously, the word "mechanism" is here a parable of how social intentions, goals and behaviors are causally connected.

It should explain how social activity worked, rather than why the traits contributing to these activities or workings are there



What is a “Social Mechanism”

Is there any human aspect that cannot can be “simulated” mechanically?

SOCIAL INTERACTION

Towards a theory of “action”

A Theory of Social Action (Leont’iev 1974)

Social action can be defined in terms of purposeful changing of natural and social reality. Social actions are goal-directed processes that must be undertaken to fulfill some need or motivation. They are conscious (because one holds a goal in mind), and different actions may be undertaken to meet the same goal.

However, an action can be an intentional action without the actor having to be aware of the intention from moment to moment. Motivations or intentions are not just conditions for developing cognitive activity, but real factors influencing productivity and perceivable structure.

Theory of Agency (Bourdieu, Giddens)

"agency" refers to the capacity of individual humans to act independently and to make their own free choices.

Reaction against the idea that our social existence is largely determined by the overall structure of society.

This theory sees structure and agency as Complementary **forces** - structure influences human behaviour, and humans are capable of changing the social structures they inhabit.

SOCIAL INTERACTION

Towards a theory of “action”

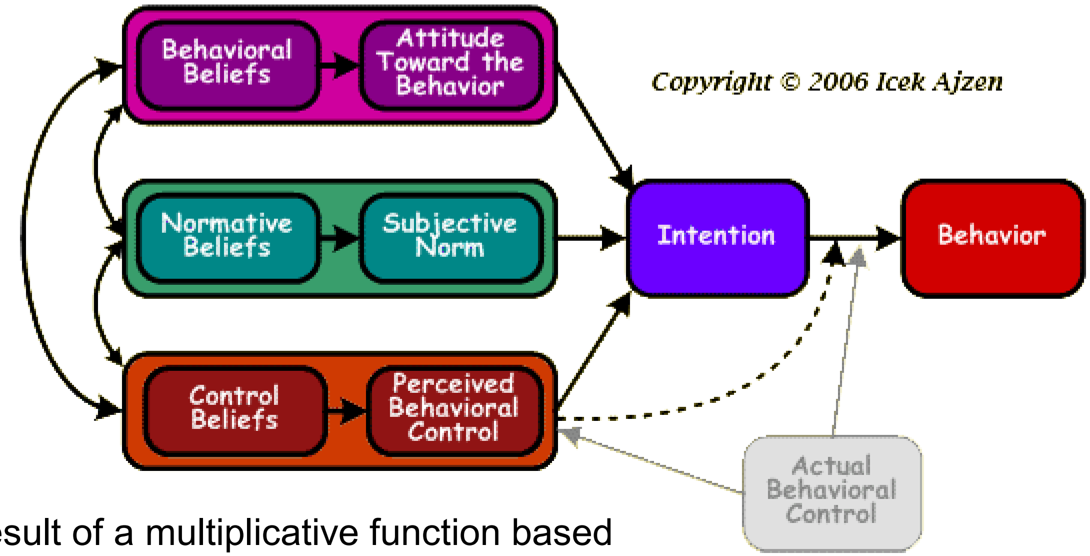
A Theory of Social Action (Leont’iev 1974)

Social actions cannot be understood without a frame of reference created by the corresponding social motivation or *intention*. Leont’ev describes *social activity* as being composed of **subjects, needs, motivations, goals, actions** and **operations** (or behavior), together with **mediating artifacts** (signs, tools, rules, community, and division of labor)

- A subject is a person or group engaged in an activity.
- An intention or motivation is held by the subject and it explains activity.
- Activities are realized as individual or cooperative *actions*. Chains and networks of such actions are related to each other by the same overall object and motivation.
- Actions consist of chains of operations, which are well defined behaviors used as answers to conditions faced during the performing of an action.
- Activities are oriented to motivations, that is, the reasons that are impelling by themselves.
- Each motivation is an object, material or ideal, that satisfies a need.
- Actions are the processes functionally subordinated to activities; they are directed at specific conscious goals.
- Actions are realized through operations that are the result of knowledge or skill, and depend on the conditions under which the action is being carried out.

Social Influence Theory

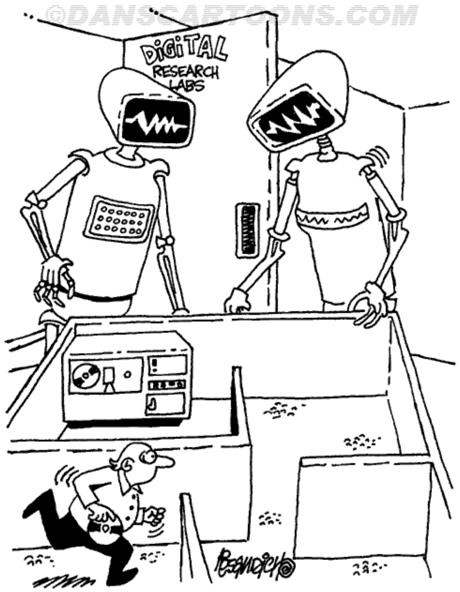
M Lewenstein, A Nowak, B Latané – *Statistical mechanics of social impact* Physical Review A, 1992



$I = f(SIN)$.

Social impact appears to be the result of a multiplicative function based on the number of people acting on the target. Within this equation, the strength (S) is a measure of how much influence, power, or intensity the target perceives the source to possess.
Immediacy (I) takes into account how recent the event occurred and whether or not there were other intervening factors.

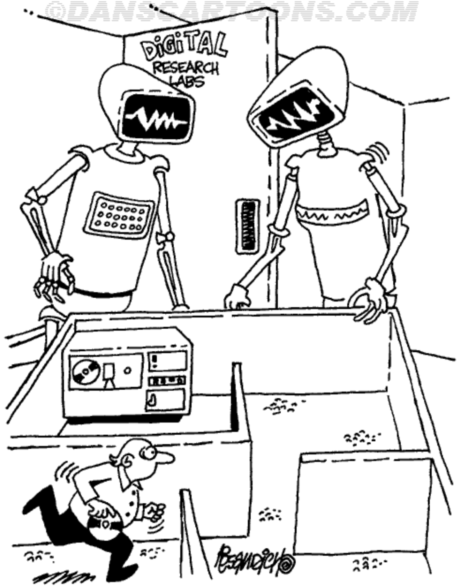
Furthermore,
$I = sN^p$
That is, some power (p) of the number of people (N) multiplied by the scaling constant (s) determines social impact.



COMPUTER SIMULATION

Why do I what I do the way I do?

Because other people do the things they do in the way they do



COMPUTER SIMULATION

Why am doing this?
Because other people do the things they do in the way they do”

I’M NOT DOING WHAT MY NEIGHBOUR DOES
HOWEVER, MY RATIONAL AND IRRATIONAL DECISSIONS
ARE AFFECTED BY THE WAY MY NEIGHBOURS
TAKE RATIONAL AND IRRATIONAL DECISSIONS

SOCIAL INTERACTION

SOCIAL INTERACTION

Towards a theory of "action"

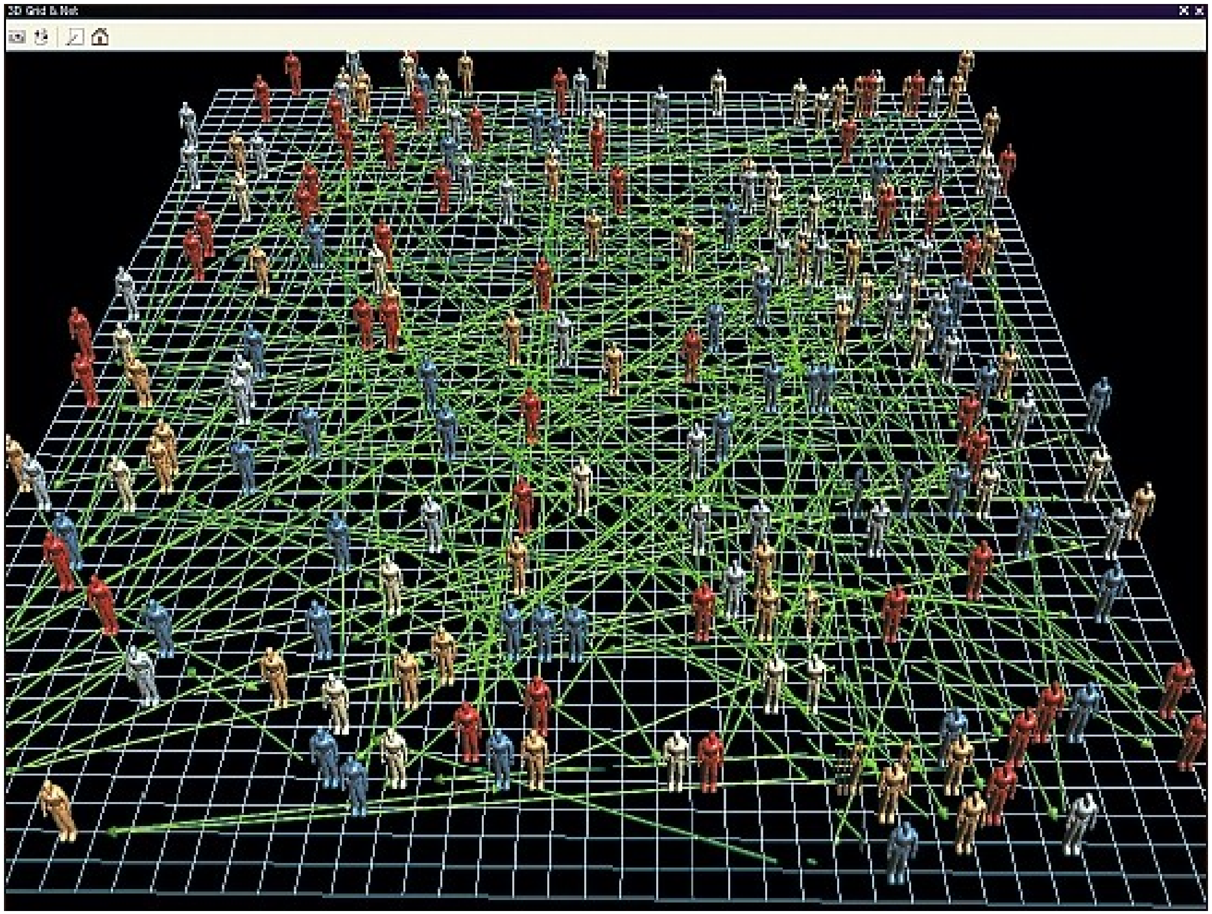
Theory of Agency (Beyond Bourdieu, Giddens)

Collective action	⇄	Individual Action

↓ In case of predominance ↓

Regularity, order | **Irregularity, chaos**

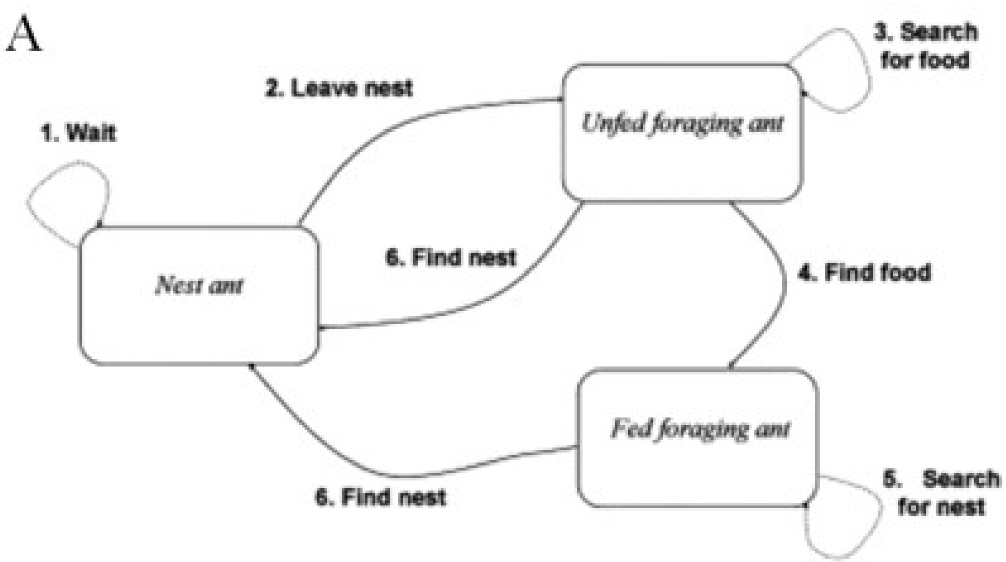
RUNING THE SIMULATION



Let us execute the Model:

Agents “act”,
They move,
They use energy
They acquire energy
They reproduce
They interact with others
They change their
previous knowledge

RUNING THE SIMULATION

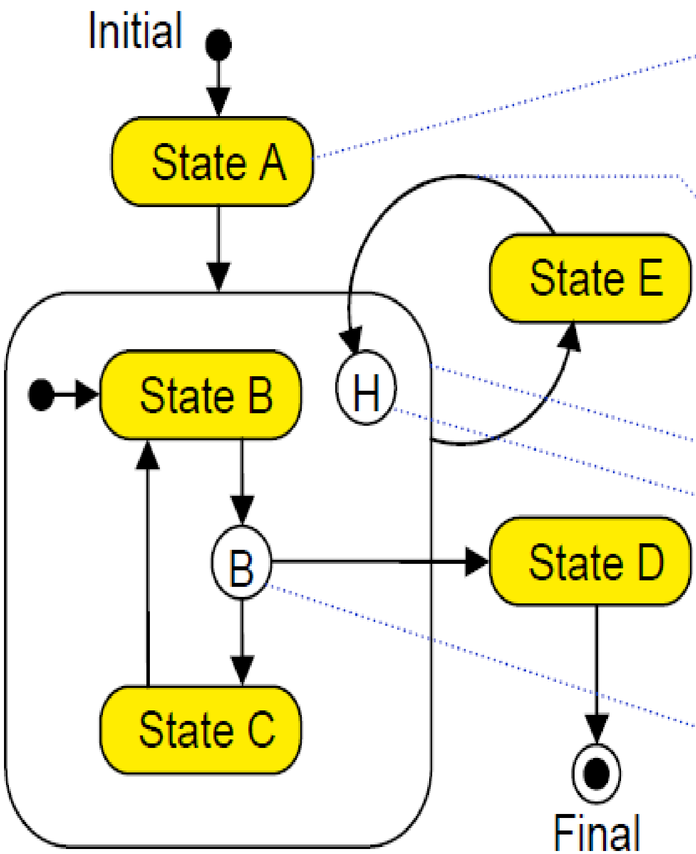


To implement activity we have to specify the order in which events happen.

A cycle: all an agent shoul do in
one day,
one season
one year
one hundred years

Predator-Prey classical model

RUNING THE SIMULATION:



Simple State
Control is always located in one of the simple states. States have Entry and Exit actions

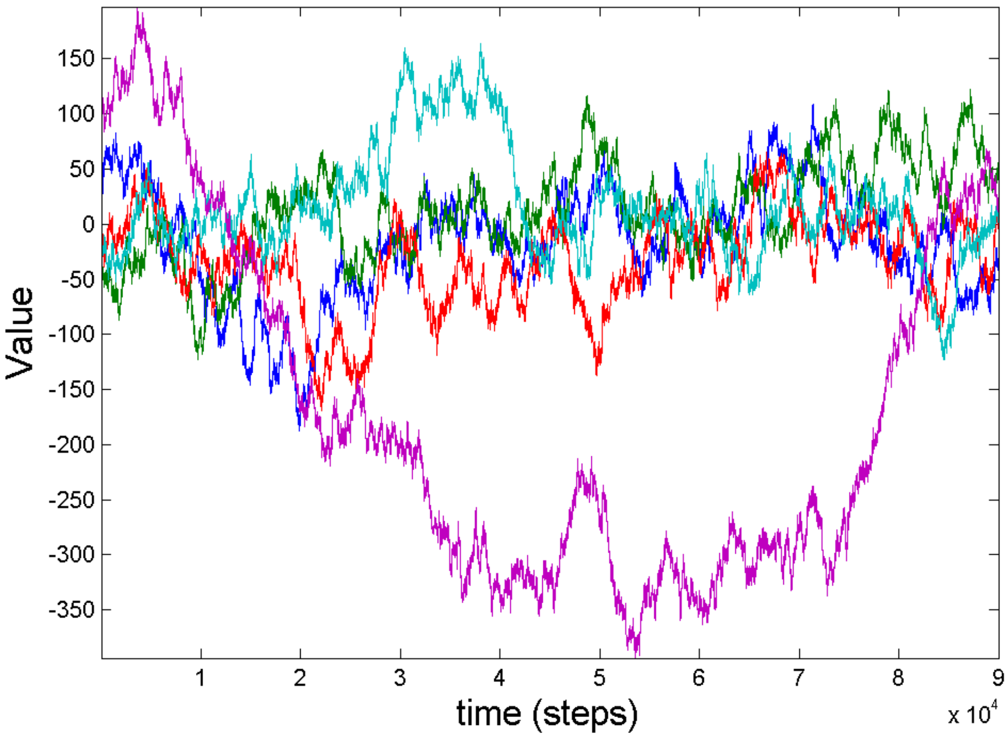
Transition
Can be triggered by an external or internal event, condition or timeout. Has Action

Composite State
A group of states with common behavior

History Pseudo State
Denotes last visited state in the composite state

Branch Pseudo State
Specifies conditional branching of transitions

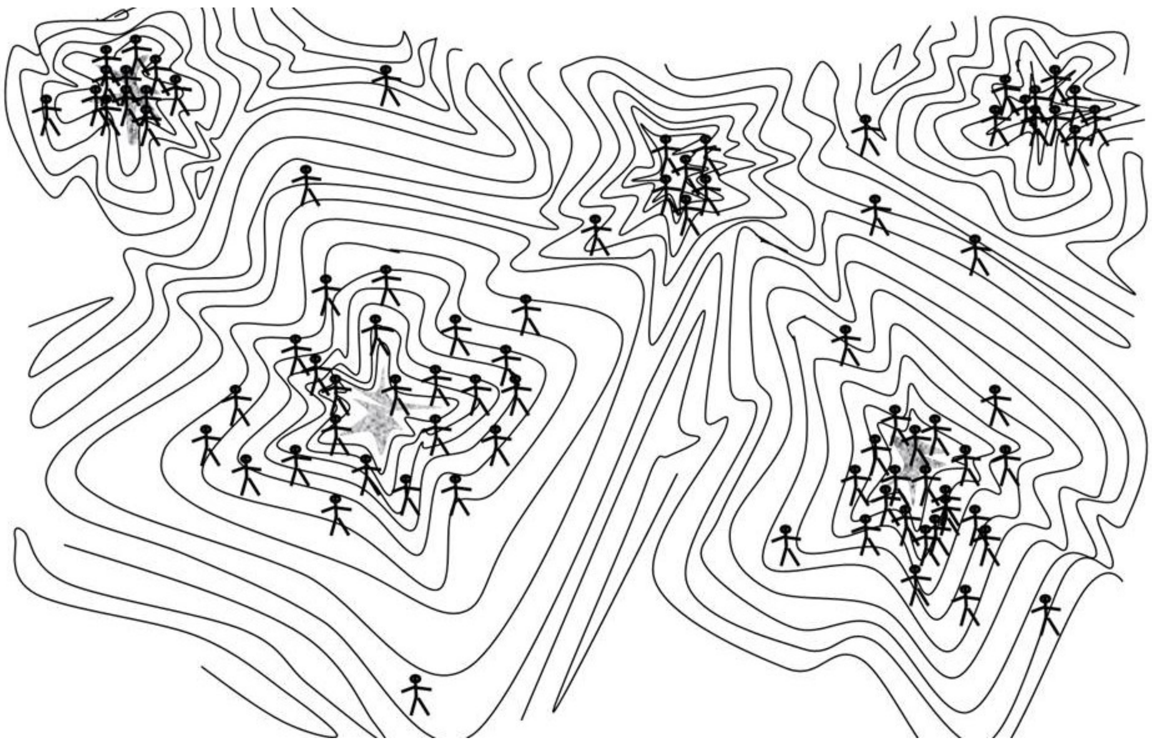
RUNING THE SIMULATION: The Idea of Time



As soon as attribute and global
Variables change their values
We obtain an idea of time.

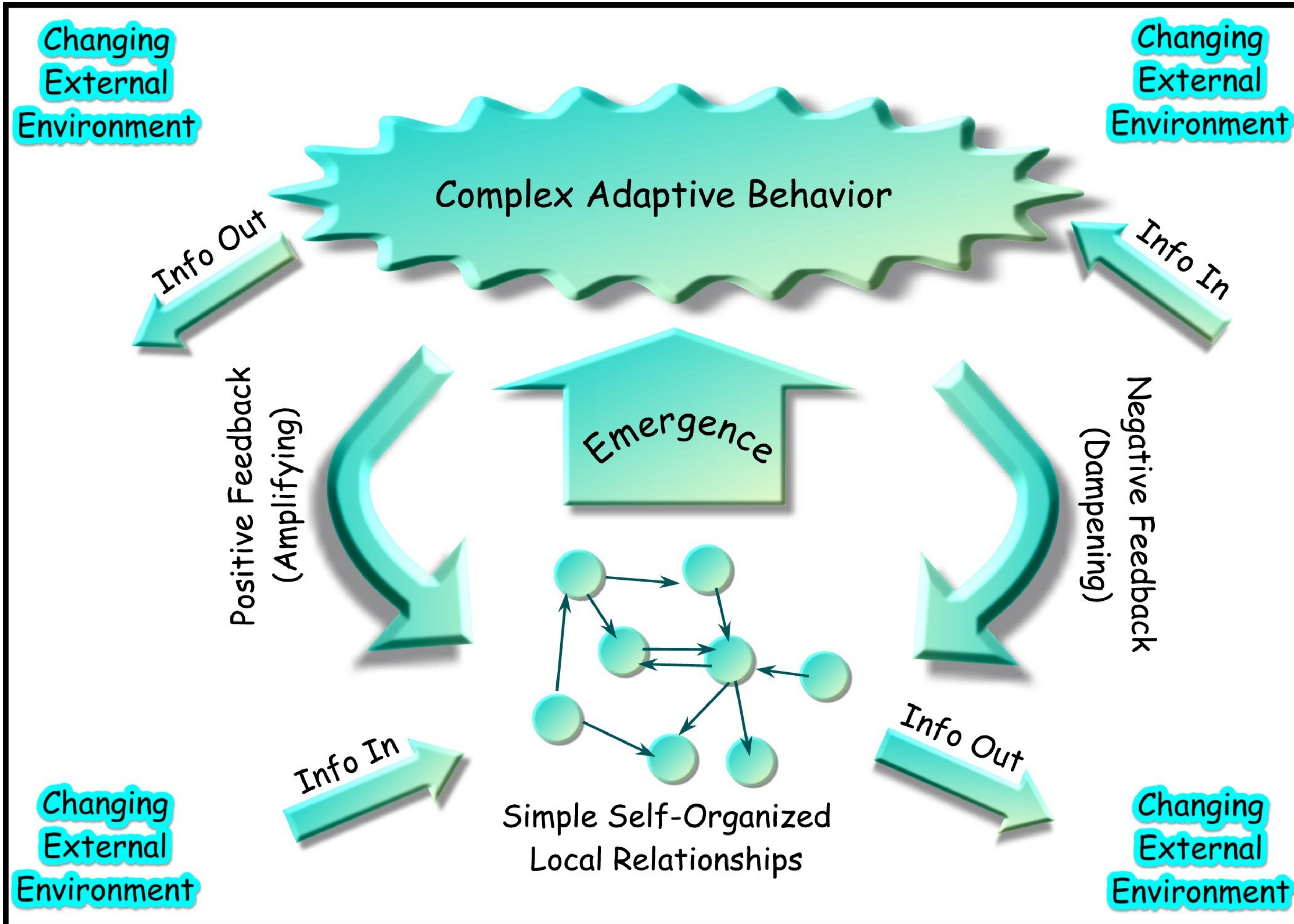
Time as the sequence of changes

RUNING THE SIMULATION: emergent behavior

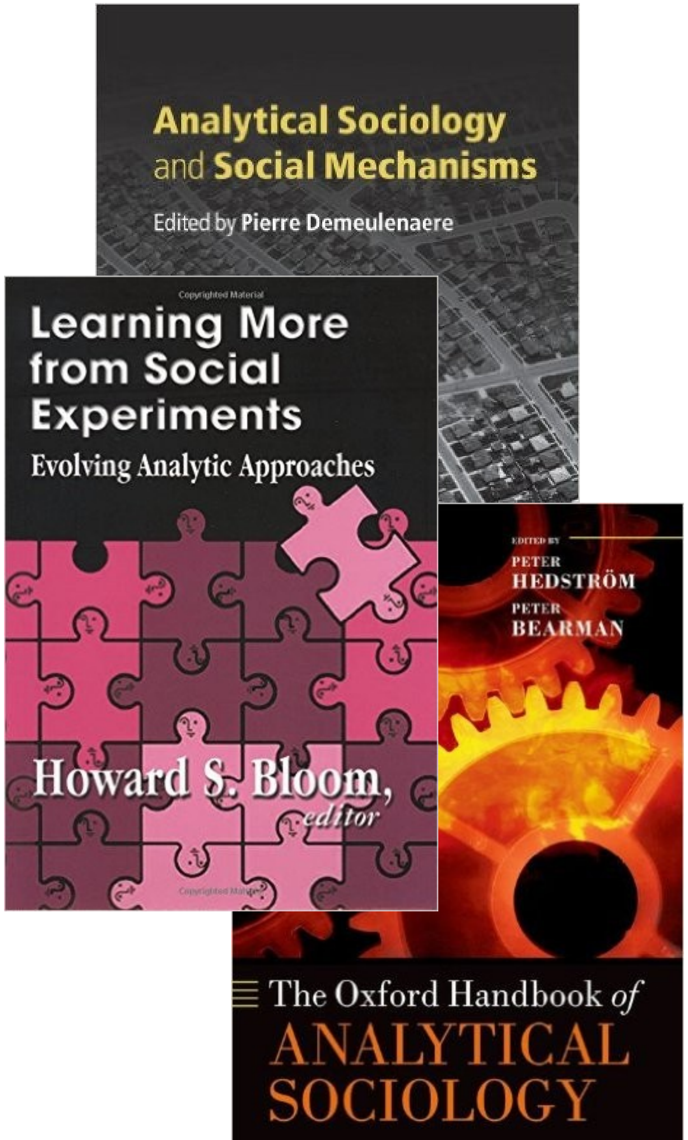


But “changes” are not easy to detect, because They are not sequential ror linearly related:

EMERGENCE is a process whereby larger entities, patterns, and regularities arise through interactions among smaller or simpler entities that themselves do not exhibit such properties


Changing External Environment
Changing External Environment
Complex Adaptive Behavior
Info Out
Info In
Emergence
Positive Feedback (Amplifying)
Negative Feedback (Dampening)
Info In
Info Out
Simple Self-Organized Local Relationships
Changing External Environment
Changing External Environment

MONITORING THE SIMULATION



We should create numeric output variables to "measure"
the system dynamics.

THE IDEA OF "SOCIAL INDEX"

It is a composite measure, i.e. measurements based on multiple data items.
Three common composite measures include:
indexes - measures that summarize and rank specific observations (usually on the ordinal scale),
scales - advanced indexes whose observations are further transformed (scaled) due to their logical or empirical relationships;

J. A. BARCELÓ, F. DEL CASTILLO ,
L. MAMELI, F.J. MIGUEL QUESADA, R. DEL OLMO, D. POZA, X. VILA

Universitat Autònoma Barcelona
Universidad de Burgos, Universidad de Valladolid, Universidatat de Girona

SIMULATING ETHNOGENESIS AND CULTURAL DIVERSITY IN SMALL-SCALE SOCIAL FORMATIONS

Laboratory for Socio Dynamics Simulation

UNIVERSIDAD DE BURGOS

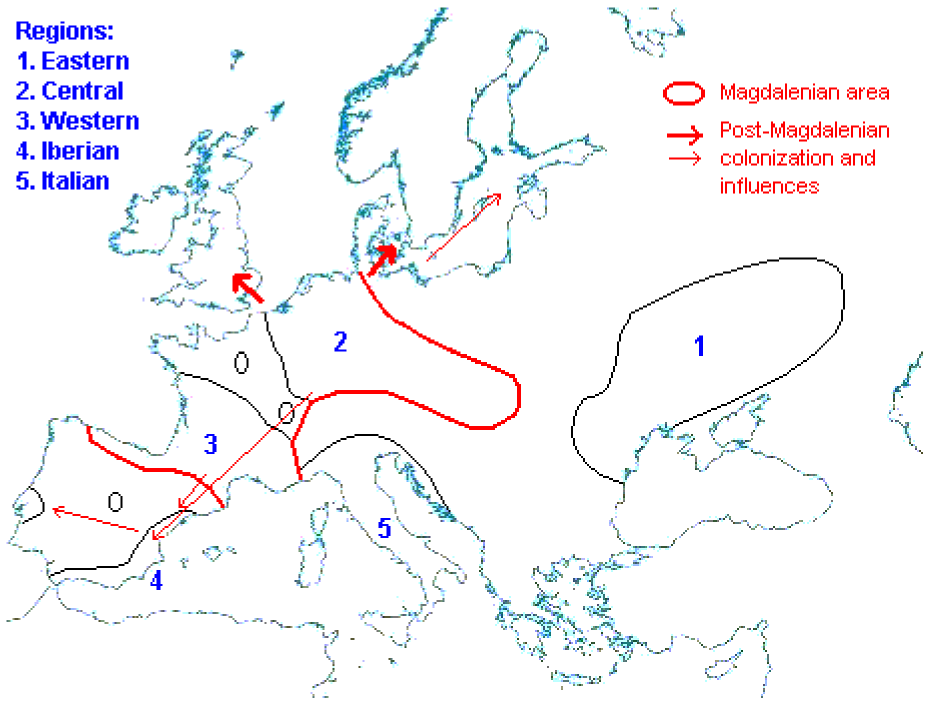
SimulPast
....simulating the past to understand human behaviour

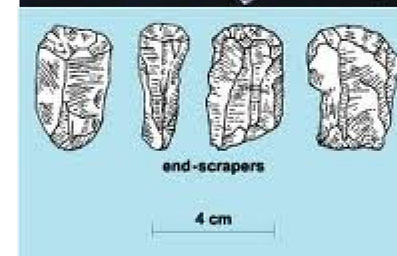
GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
PROGRAMA ingenio 2010

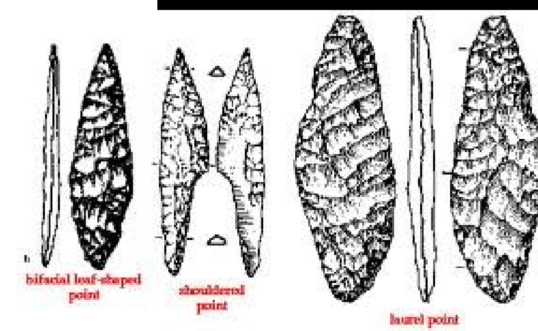
- Barceló, J.A.,Del Castillo, F., Del Olmo, R., Mameli, L., Miguel Quesada, F.J., Poza, D, Vilà, X., 2014, "Social Interaction in Hunter-Gatherer Societies: Simulating the Consequences of Cooperation and Social Aggregation. *Social Science Computer Review*, vol. 32 no. 3 417-436.

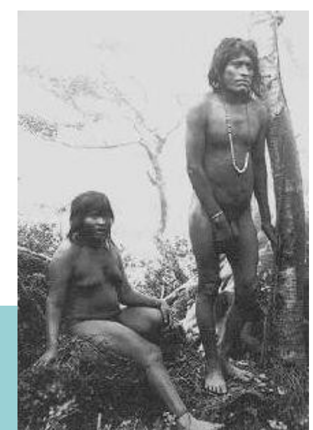
- Barceló, J.A., Del Castillo, F., Del Olmo, R., Mameli, L., Miguel Quesada, F.J., Poza, D., Vila, X., 2015,Simulating Patagonian Territoriality in prehistory: Space, Frontiers and networks among Hunter-gatherers. In *Agent-based Modeling and Simulation in Archaeology*. Edited by G. Wurzer, K. Kowarik and H. Reschreiter. Springer-Verlag, Berlin-New York. Advances in geographic Information Science. pp. 243-289.DOI 10.1007/978-3-319-00008-4__10

Archaeologists have been doing material classifications to discover “cultural” limits and differentiation, as surrogates of different ethnic groups, avoiding a careful analysis of the very meaning of “ethnicity”









SOCIAL VARIABILITY

Design Concepts:
Ethnicity as Cultural Differentiation

An **ethnic group** is a group of people whose members explicitly regard themselves and are regarded by others as truly distinctive, through a common heritage that is real or assumed- sharing "cultural" characteristics.

The emergence of such identification is the consequence of different historical processes and social mechanisms, which take place within the webs of group and/or individual interaction.

Design Concepts:
Ethnicity as Cultural Differentiation

The question is "*why* groups of people are the way they are" in terms of *how* they acted within a social aggregate their previous activity contributed to build. The complex interplay of social actions, people and the consequences of their actions explain ethnicity by showing how social aggregation fit into a causal structure, that is to say, a vast network of interacting *actions* and *entities*, where a change in a property of an entity dialectically produces a change in a property of another entity

Design Concepts:
Ethnicity as Cultural Differentiation

Cultural Standartizacion as an Emerging Phenomenon

As a consequence of different forms of social interaction and exchange between related individuals cultural consensus may emerge, and communities of people can aggregate into greater groups culturally homogenous, what affect social reproduction, increasing similarity in the long run, and reducing the risk of being attacked by groups identified as “enemies” (out of the new cultural consensus).

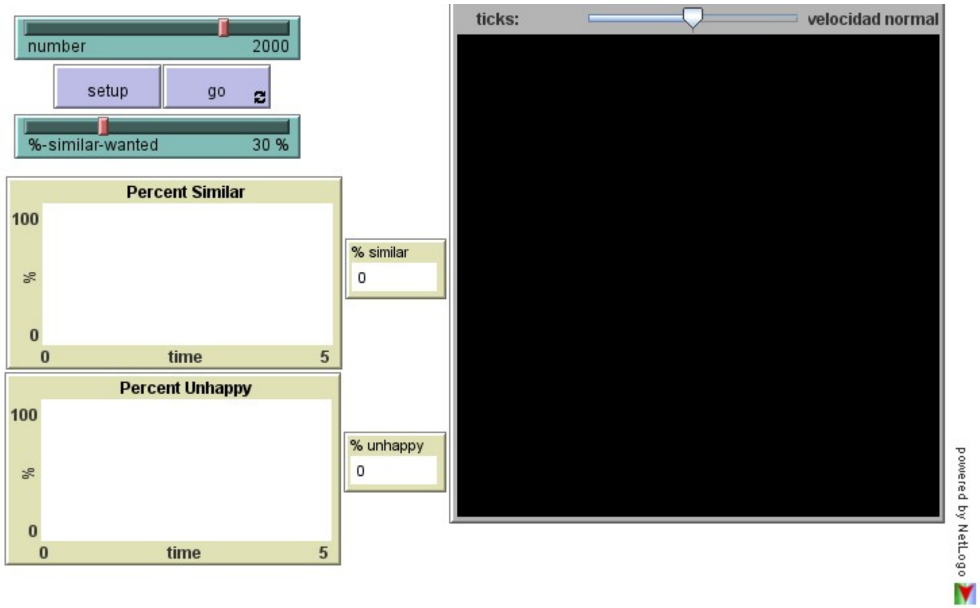
Design Concepts:
Ethnicity as Cultural Differentiation

ethnogenesis (at the macro-scale) appears as a consequence of a long period of repeated constraints to cooperation due to stable identity formation (at the micro-scale) .

Both are a contradiction between social inertia (knowledge inheritance) and cultural consensus (social similarity) built during cooperation and labor exchange.

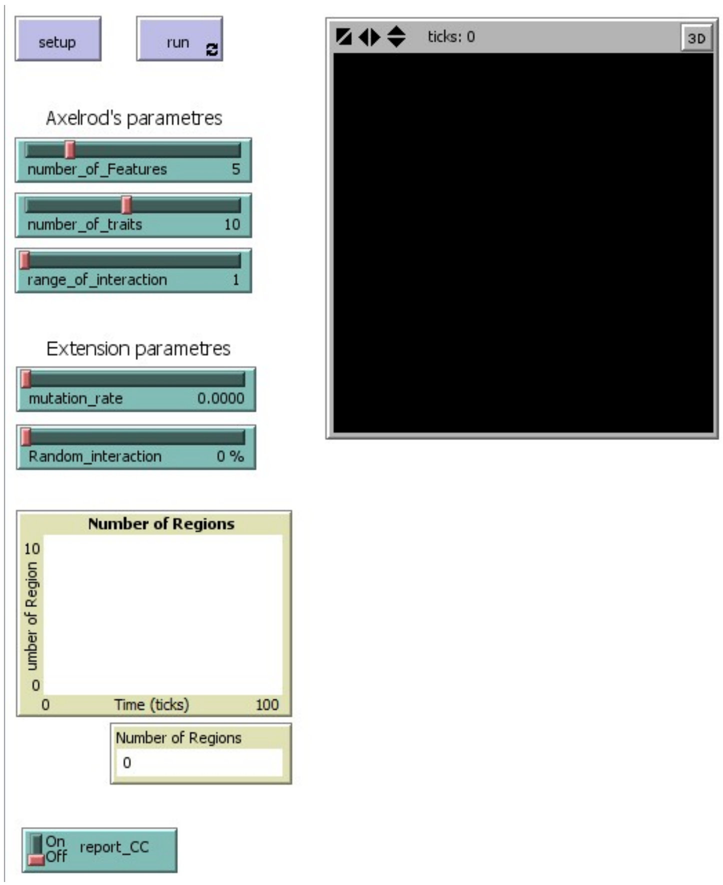
Design Concepts:
Ethnicity as Cultural Differentiation

Schelling proposed a model of a population randomly displaced on a two dimensional grid. The grid hosts the agents and each agent has a neighbor made up of four cells, those immediately up, down, left and right to the agent. Each agent is happy" or not depending on the number of its neighbors: if the percentage of neighbors of the same breed over the total number of neighbors is under a *fix*ed threshold, the person is unhappy. Agents move in order to enhance the probability of being happy with most neighbours. Schelling shows that after a limited number of moves, a segregation pattern emerges, and that this macro"behavior is largely unpredictable based only on the only simple rule each agent follows, namely that to move if it's unhappy.



SCHELLING *Segregation*

Design Concepts:
Ethnicity as Cultural Differentiation



AXELROD’s *Diffusion of Culture*

Axelrod's model of cultural dissemination. It models a population of actors that hold a number of cultural attributes (called features) and interact with their neighbors. Dynamics are based on two main mechanisms. First, agents tend to chose culturally similar neighbors as interaction partners (homophily). Second, during interaction agents influence each other in a way that they become more similar. The interplay of these mechanisms either leads to cultural homogeneity (all agents are perfectly similar) or the development of culturally distinct regions. The model allows studying to which degree the likelihood of these two outcomes depends on the size of the population, the number of features the agents hold, the number of traits (values) each feature can adopt and the neighborhood size (interaction range).

Design Concepts:
Ethnicity as Cultural Differentiation

DIFFERENCES WITH OUR MODEL:

1) Integrating Axelrod and Schelling: mobility is allowed, and transmission of cultural features
2) Culture is not fixed, but evolve as soon as cooperation appears to be advantageous
3) Random cultural drift simulates internal process in addition to external interaction
4) Movement is not random, but depends on survival
5) Survival depends on cooperation
6) Cultural transmission depends also on survival and hence on cooperation
7) Cooperation and reciprocity depends on the probabilities of survival

Purpose:

how diversity and self-identification can emerge in small-scale societies

In this preliminary and simplified computer simulation we are exploring the consequences that labor exchange and territorial mobility in an artificial unconstrained world has on identity formation and negotiation.

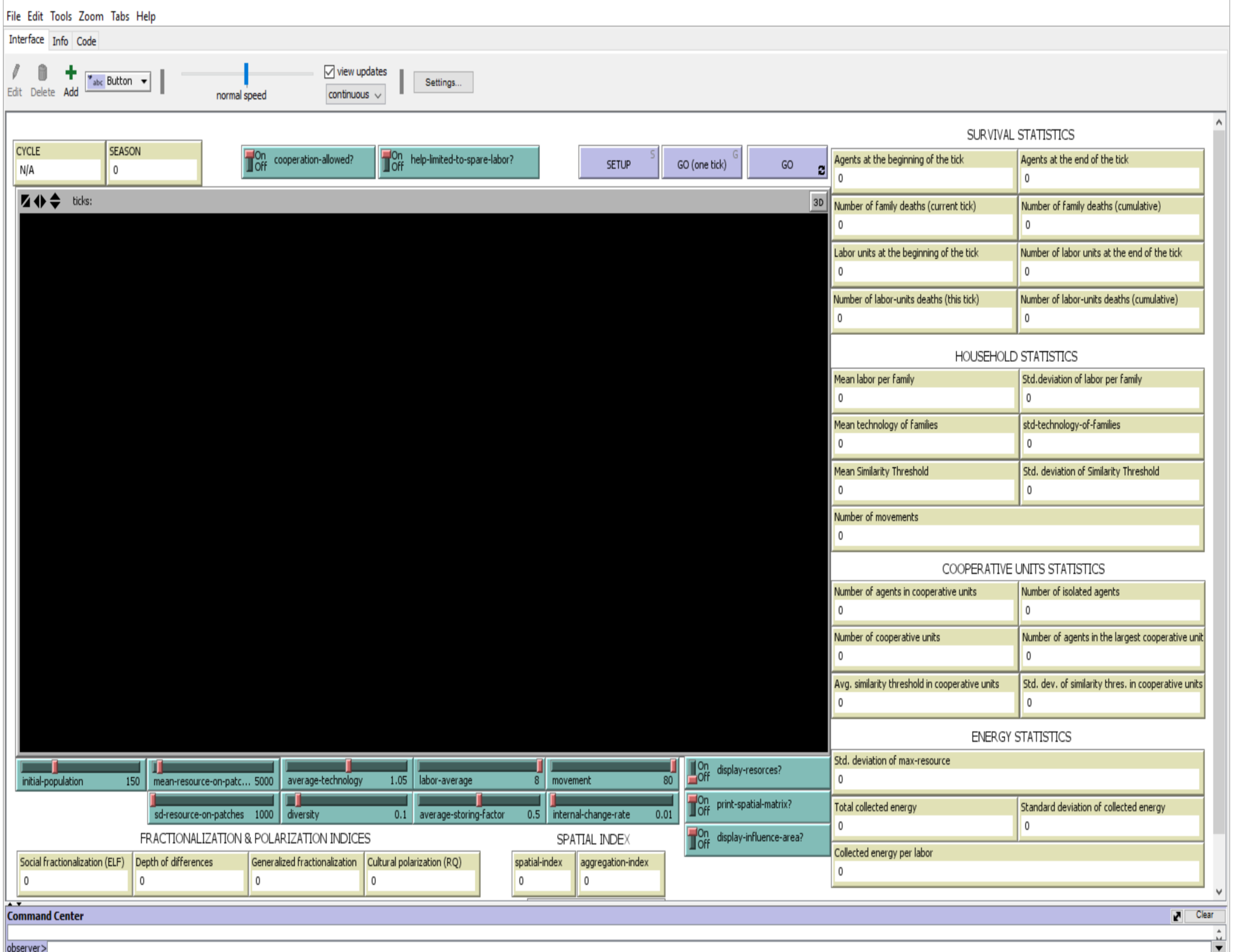
We expect to be able to discern if cultural diversity emerge as a result of social decisions only, or if it is the result of constraints on mobility generated by geography and the irregular distribution of resources, both in space and time.

Purpose:

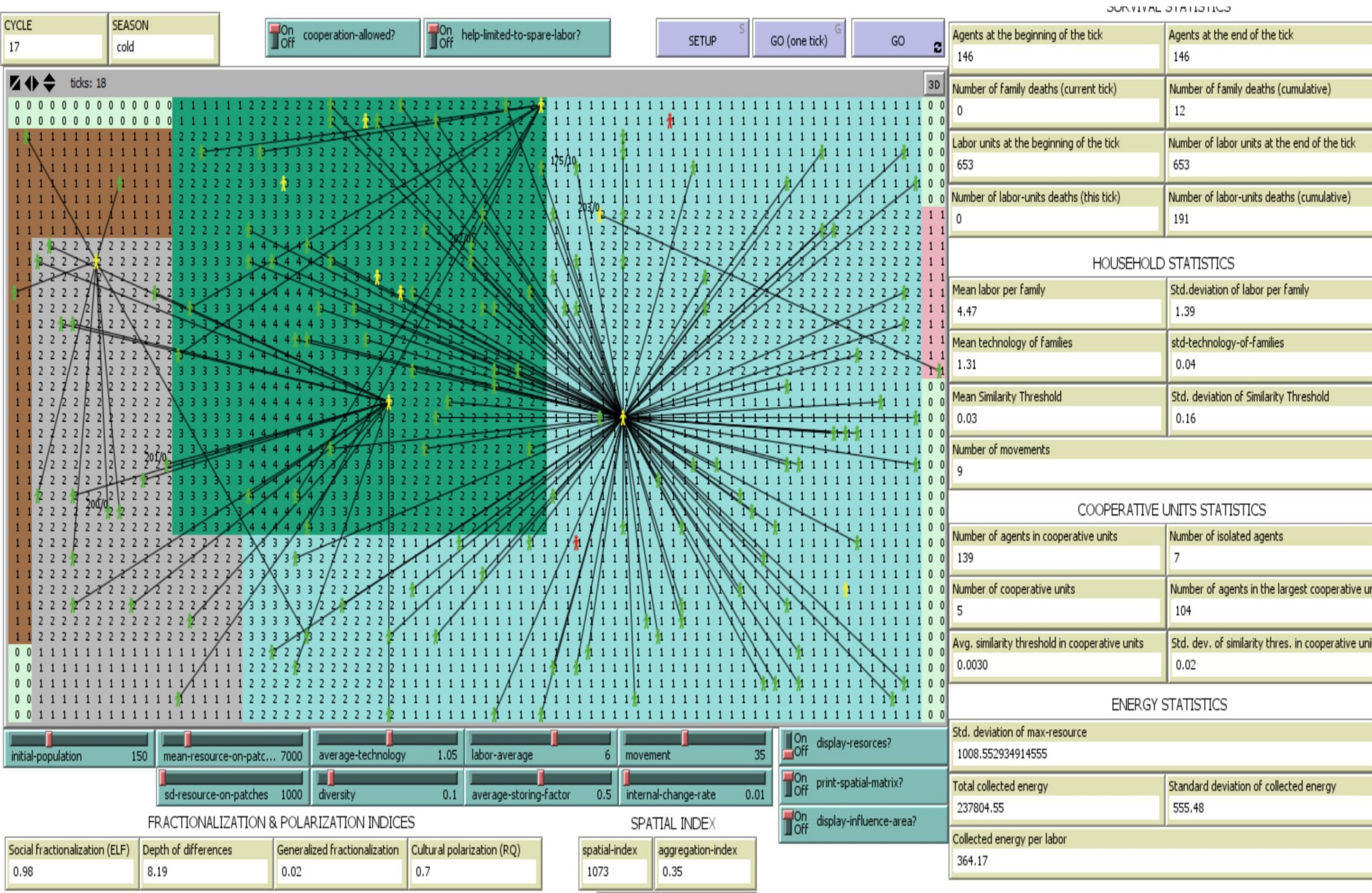
how diversity and self-identification can emerge in small-scale societies

Agents should be able to update and consequently modify their actual identity ("culture") when what they inherited proves to be not useful to cooperate.

What agents have inherited at birth is usually a central tendency of parents identity. Given that the process of mating and selecting reproductive partner is socially and politically mediated, the cultural consensus to be transmitted depends on the way such cultural consensus is built at the level of the reproductive unit, and hence on the social and political origins of the reproductive unit itself ("family").



http://ingor.ubu.es/models/patagonia/simple1.5



CYCLE
17
SEASON
cold
On Off cooperation-allowed?
On Off help-limited-to-spare-labor?
SETUP
GO (one tick)
GO
ticks: 18
3D
175/10
203/0
201/0
200/0
initial-population 150
mean-resource-on-patc... 7000
average-technology 1.05
labor-average 6
movement 35
sd-resource-on-patches 1000
diversity 0.1
average-storing-factor 0.5
internal-change-rate 0.01
On Off display-resorces?
On Off print-spatial-matrix?
On Off display-influence-area?
FRACTIONALIZATION & POLARIZATION INDICES
Social fractionalization (ELF)
0.98
Depth of differences
8.19
Generalized fractionalization
0.02
Cultural polarization (RQ)
0.7
SPATIAL INDEX
spatial-index
1073
aggregation-index
0.35
SURVIVAL STATISTICS
Agents at the beginning of the tick
146
Agents at the end of the tick
146
Number of family deaths (current tick)
0
Number of family deaths (cumulative)
12
Labor units at the beginning of the tick
653
Number of labor units at the end of the tick
653
Number of labor-units deaths (this tick)
0
Number of labor-units deaths (cumulative)
191
HOUSEHOLD STATISTICS
Mean labor per family
4.47
Std.deviation of labor per family
1.39
Mean technology of families
1.31
std-technology-of-families
0.04
Mean Similarity Threshold
0.03
Std. deviation of Similarity Threshold
0.16
Number of movements
9
COOPERATIVE UNITS STATISTICS
Number of agents in cooperative units
139
Number of isolated agents
7
Number of cooperative units
5
Number of agents in the largest cooperative unit
104
Avg. similarity threshold in cooperative units
0.0030
Std. dev. of similarity thres. in cooperative units
0.02
ENERGY STATISTICS
Std. deviation of max-resource
1008.552934914555
Total collected energy
237804.55
Standard deviation of collected energy
555.48
Collected energy per labor
364.17

What is possible within the model?

Exploring the Parametric Space

What is possible within the model?

Exploring the Parametric Space

SURVIVAL STATISTICS

Agents at the beginning of the tick: 146	Agents at the end of the tick: 146
Number of family deaths (current tick): 0	Number of family deaths (cumulative): 12
Labor units at the beginning of the tick: 653	Number of labor units at the end of the tick: 653
Number of labor-units deaths (this tick): 0	Number of labor-units deaths (cumulative): 191

HOUSEHOLD STATISTICS

Mean labor per family: 4.47	Std.deviation of labor per family: 1.39
Mean technology of families: 1.31	std-technology-of-families: 0.04
Mean Similarity Threshold: 0.03	Std. deviation of Similarity Threshold: 0.16
Number of movements: 9	

COOPERATIVE UNITS STATISTICS

Number of agents in cooperative units: 139	Number of isolated agents: 7
Number of cooperative units: 5	Number of agents in the largest cooperative unit: 104
Avg. similarity threshold in cooperative units: 0.0030	Std. dev. of similarity thres. in cooperative units: 0.02

ENERGY STATISTICS

Std. deviation of max-resource: 1008.552934914555	
Total collected energy: 237804.55	Standard deviation of collected energy: 555.48
Collected energy per labor: 364.17	

The Model

Do the degree of cooperation and its social consequences (identity variation at the short term) affect global identity variation at the long term?

The model has been Created to predict degree of Cultural Diversity and Ethnogenesis, which is measured according five indexes:

1. Social Fractionalization

$$ELF_j = 1 - \sum_{i=1}^{I_j} \left(\frac{n_{ij}}{N_j}\right)^2 = 1 - \sum_{i=1}^{I_j} s_{ij}^2 \qquad i = 1, \ldots, I_j$$

2. Depth of Differences

Non-normalized Euclidean distances between identity vectors.

3. Generalization of Fractionalization

$$G(S_N) = 1 - \frac{1}{N^2} \sum_{i=1}^{N} \sum_{j=1}^{N} s_{ij}$$

4. Generalized Resemblance

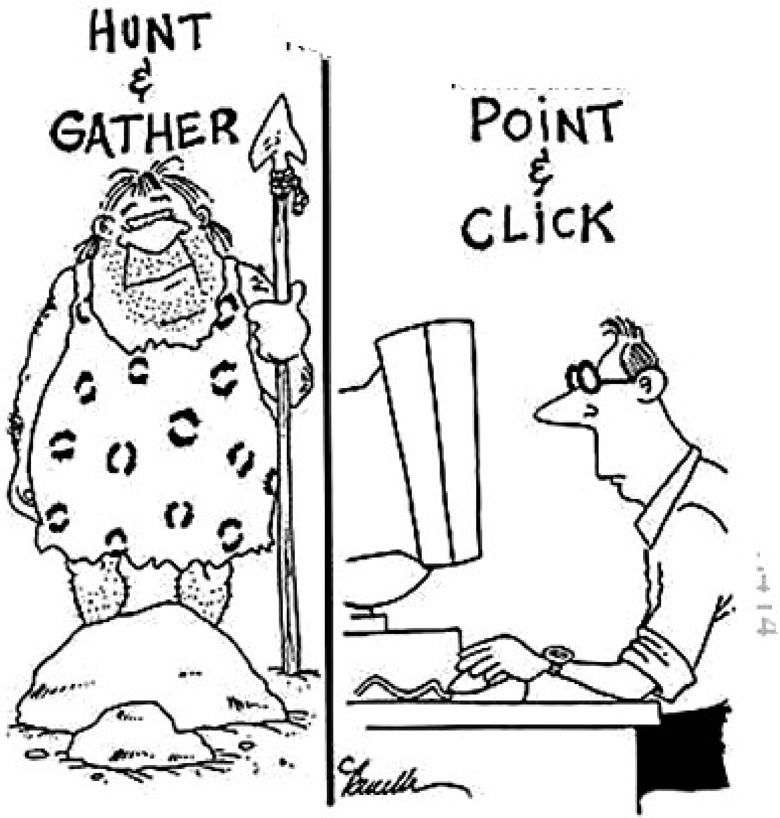
$$\mathrm{RQ} = 4 \sum_{i=1}^{k} \sum_{j \neq i} p_i^2 p_j = 4 \sum_{i=1}^{k} p_i^2 (1 - p_i) = 1 - \sum_{i=1}^{k} \left(\frac{0.5 - p_i}{0.5}\right)^2 p_i.$$

5. Generalized Spatial Aggregation and Territoriality

$$\rho = \frac{1}{n} \sum_{p=1}^{n} o_p$$

Entities, state variables and scales:

Agents

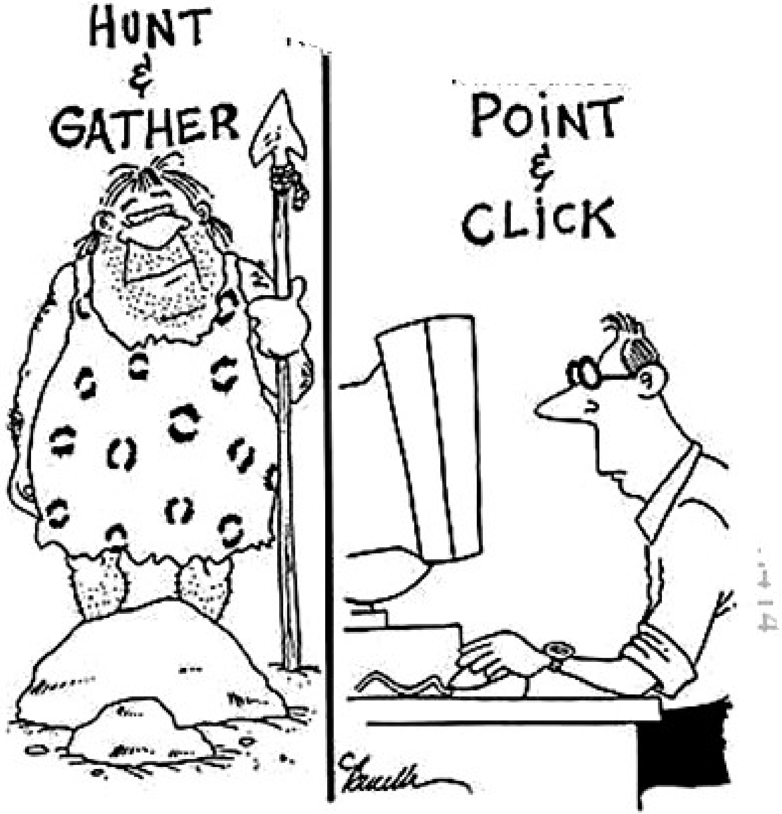


agents are modeled as a number of individuals acting as a decision unit, that is, what we usually name “family” in real live, and what anthropologists define as “domestic unit” or “household”

Agents are obliged to constant geographical mobility, given their extreme dependence to local carrying capacity and diminishing returns from labor given that they cannot restore what they have extracted from nature

Entities, state variables and scales:

Agents



AGE (number of lived time-steps at each time-step)
MAX-AGE. A condition, after what the agent dies. Fixed for all agents
SURVIVAL. Probability of survival for each agent. It depends on the actual value of energy. It determines if the household survives or dies.
LABOR UNITS: (l_i) (a Poisson distributed parameter counting the aggregated quantity of labor from all groups)
TECHNOLOGY (b_i): A parameter representing the aggregated efficiency of labor obtained when increasing the number of manufactured tools). It starts at 1 (lack of tools) and has not an upper maximum.

ENERGY = (e_i) Produced food, expressed in kilocalories.
SURPLUS (s_i) The difference between energy produced and energy consumed. It is storted for later use.
SURVIVAL THRESHOLD, ($\bar{e}_i$): in terms of the quantity of calories all agents included in an agent that represents a regional group of local groups need to be able to live a season long (six months).

Entities, state variables and scales:

Agents

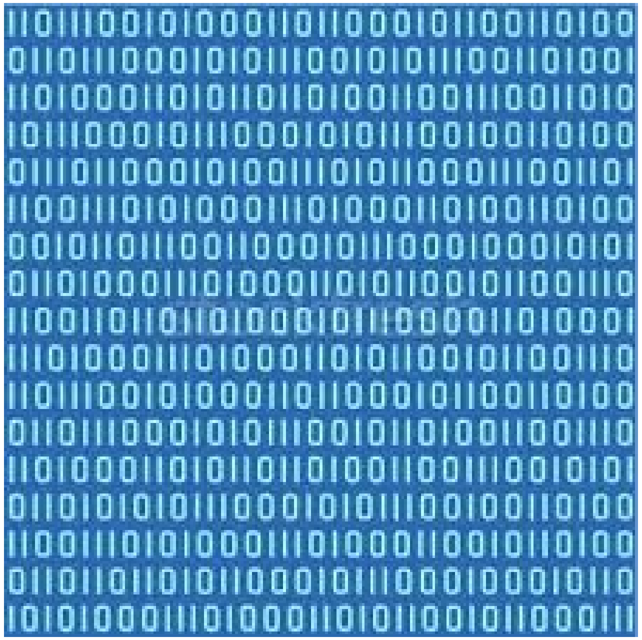
CULTURE: A 10 x 10 matrix of natural number. At the beginning of the simulation all agents have the same culture. It is a measure of IDENTITY

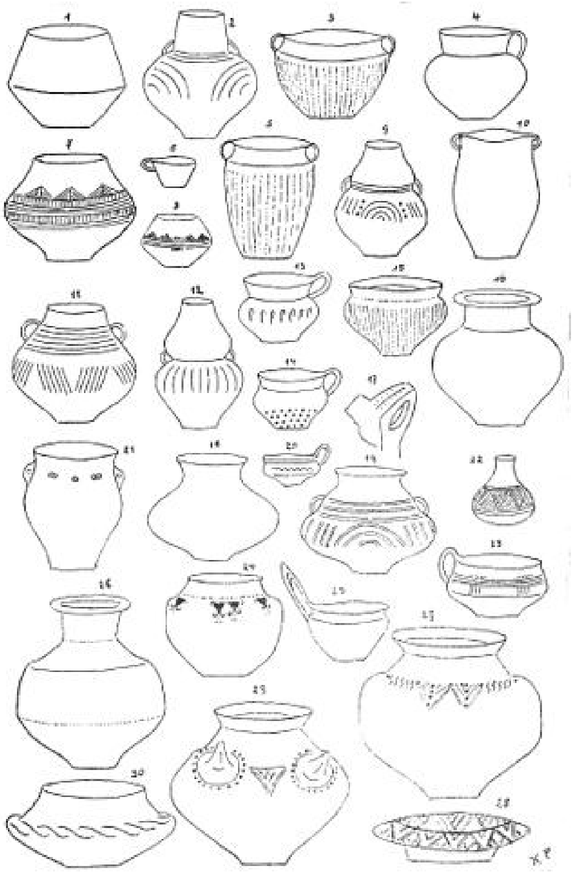
MY-GROUP A list of connected households in the same social aggregate.

MY-NEIGHBORHOOD (list of agents around)

Entities, state variables and scales:

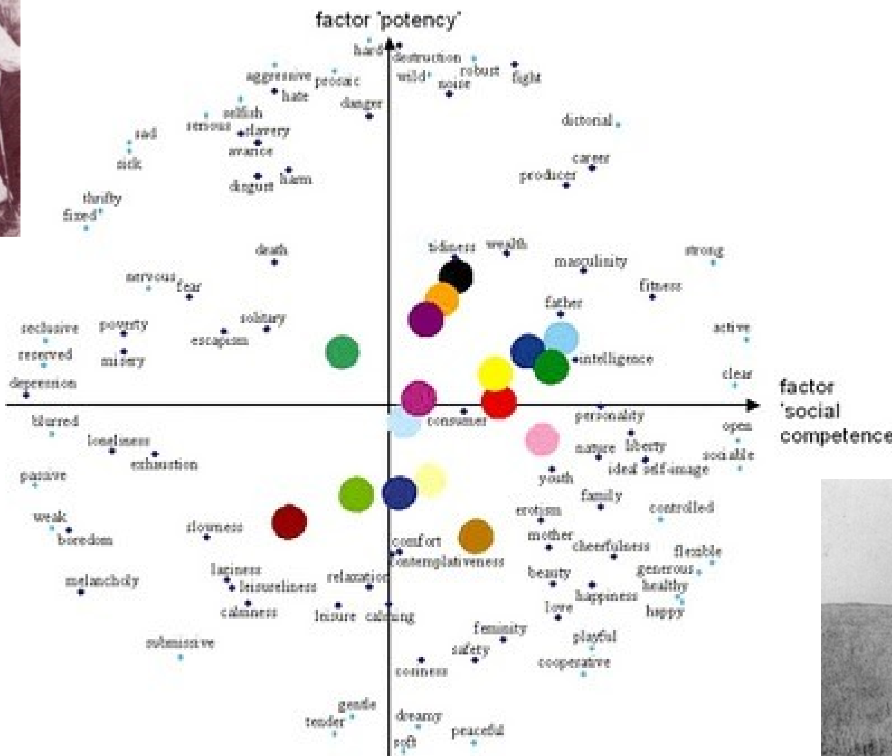
CULTURAL IDENTITY



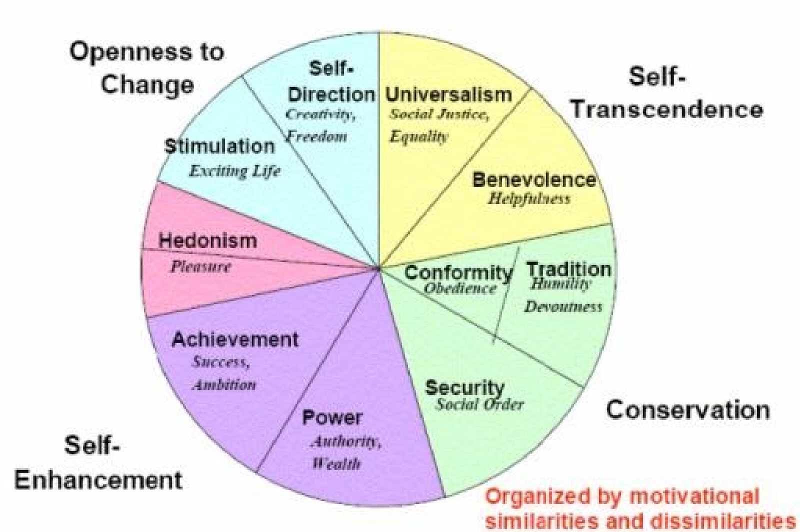


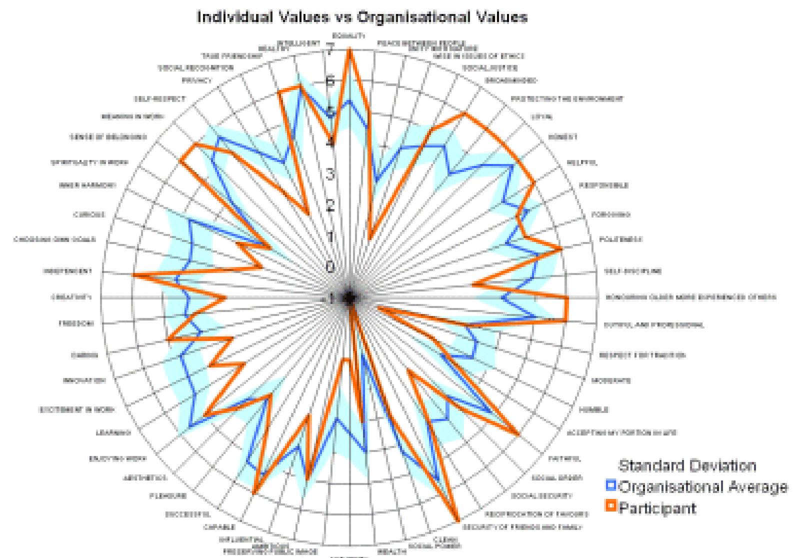
Entities, state variables and scales:

CULTURAL IDENTITY



Entities, state variables and scales:
CULTURAL IDENTITY

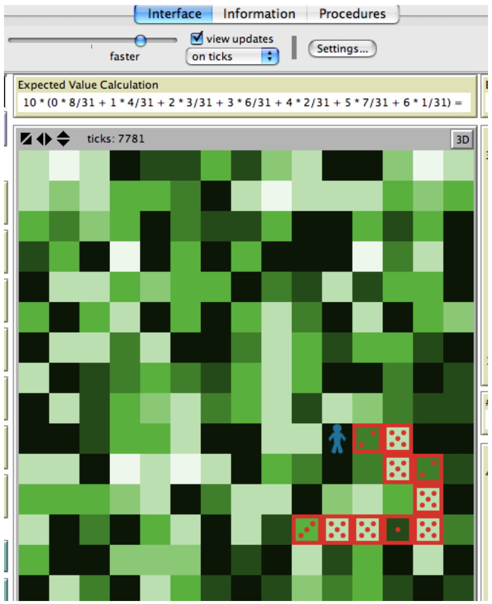




SCHWARTZ, S. H. 1992. Universals in the Content and Structure of Values: Theoretical Advances and Empirical Tests in 20 Countries. In M. P. Zanna (ed.), *Advances in Experimental Social Psychology* (Vol. 25: 1-65). San Diego, CA: Academic Press.

SCHWARTZ, S.H. 1996. Value priorities and behavior: Applying a theory of integrated value systems. In C. Seligman, J.M. Olson, & M.P. Zanna (Eds.), *The Psychology of Values: The Ontario Symposium*, Vol. 8: 1-24. Hillsdale, NJ: Erlbaum.

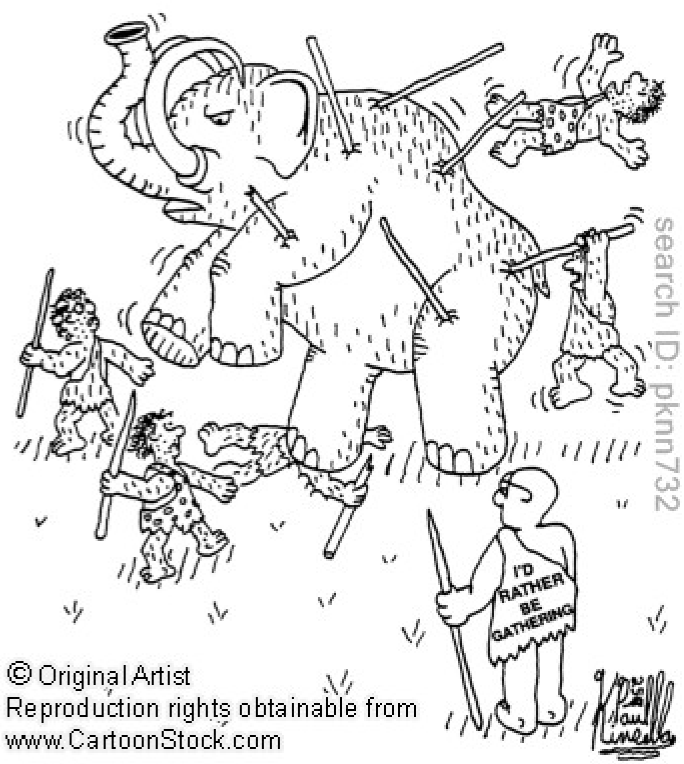
Entities, state variables and scales:
Environment



Uniform Distribution of Kilocalories:
-between 100 and 15000 ***POOR WORLD***
*between 100 and 20000
-between 100 and 25000
-between 100 and 40000
-between 100 and 50000 ***RICH WORLD***

We have built a world without topographical barriers, where **resources are irregularly distributed** across geographical space, and with a founding population having a single homogenous identity, with a constant, but random internal change rate.

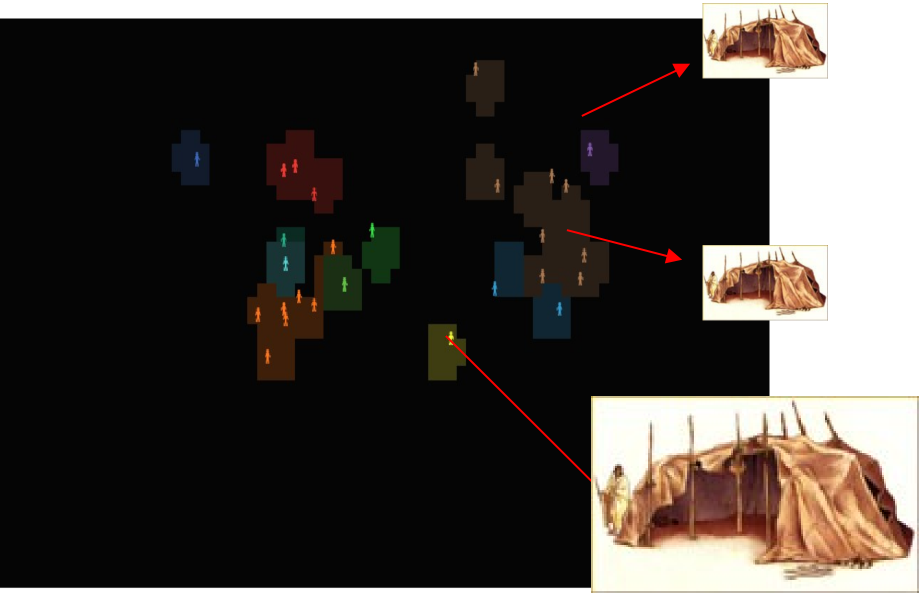
Process overview



Let us imagine a population of virtual agents, moving randomly in search for resources, and organized in households .

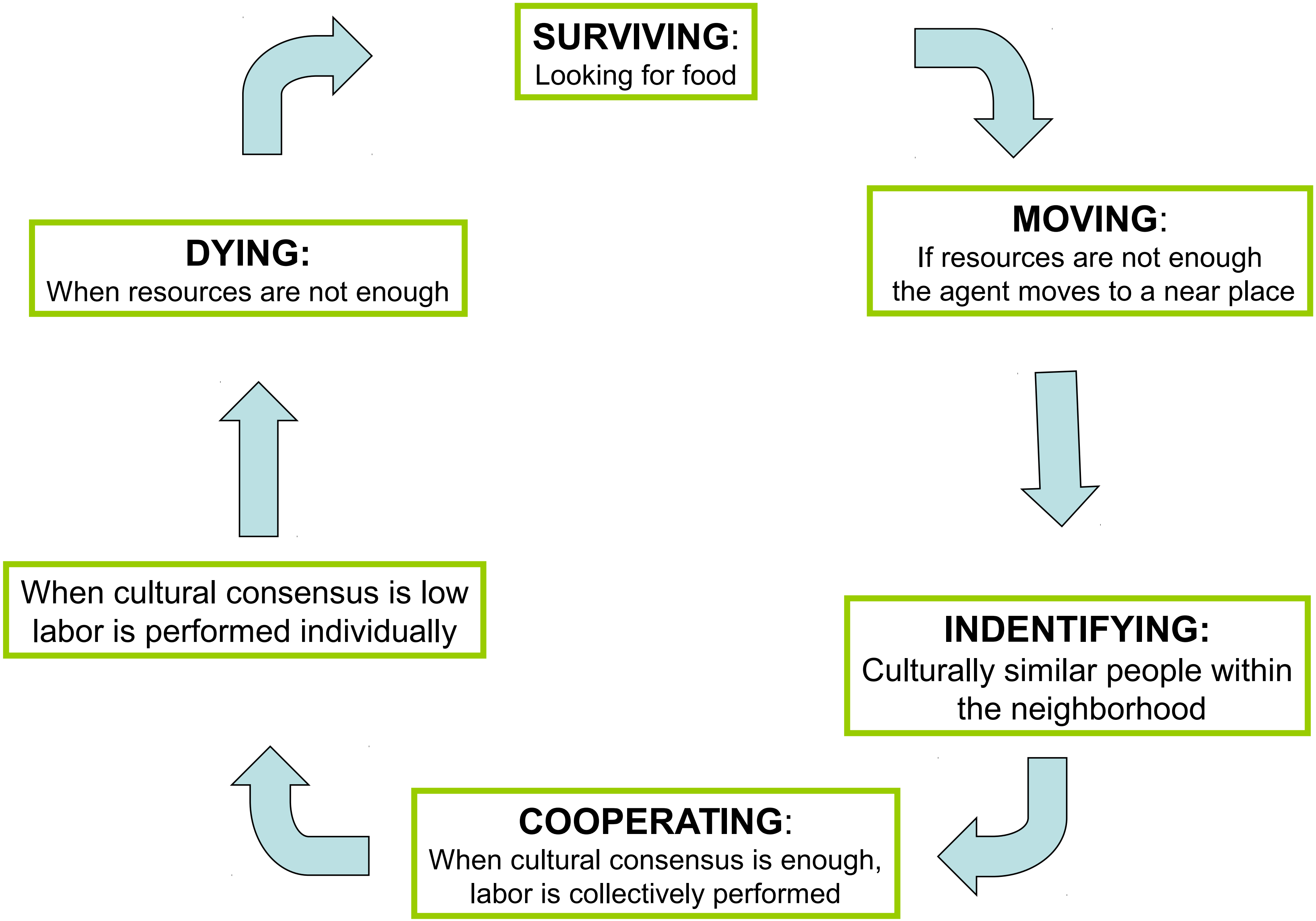
If the agent survives, and there are other agents in the neighborhood with enough cultural consensus, linked agents have the opportunity to give birth to a new agent (reproduce) and to transfer a combination of the identity of linked agents to the new generation.

Process overview



Agents: households

Agents all have a similar identity vector, and they begin working at nearby places. Very soon they begin to move to avoid diminishing returns derived from local carrying capacity. When moving, they lose contact with brothers and cousins, and their identity began to change in isolation given internal mechanisms. The greatest the geographical distance, the less the probability of renewing contacts and maintaining cultural consensus. If they randomly find a relative in their peripatetic displacements, a common identity is rebuilt, but it is a new identity and not the previous one, integrating some of the new elements that may have emerged in isolation.



Survival Cycle

Evolution of Identity Cycle

Inherent identity at birth

Use its own identity
To identify the others

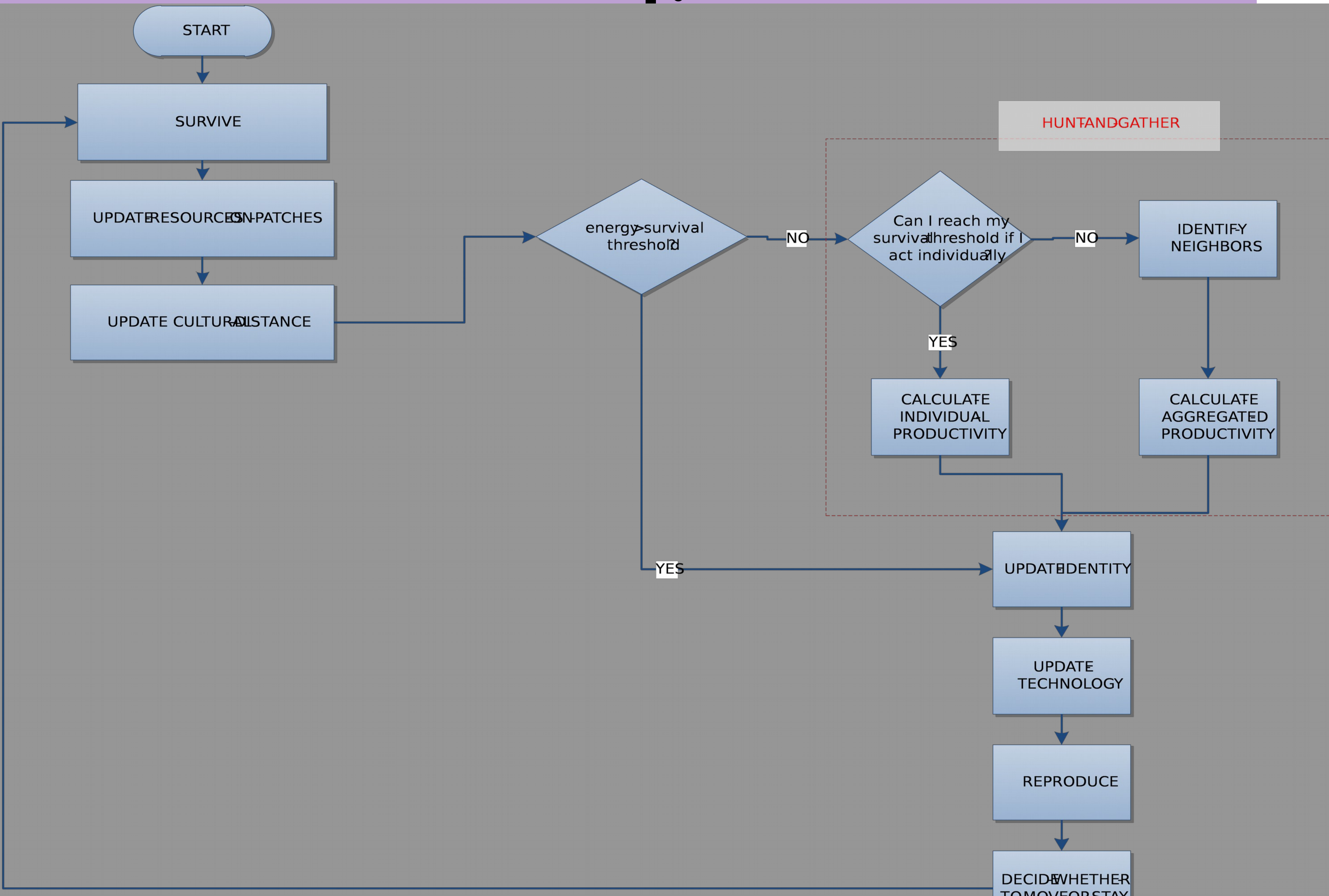
If cultural consensus is high, similarity increase

If cultural consensus is low, identity mute randomly

Every 10 cycles, 2 neighbour agents
Produce a new agent with an identity
That combines their parents identity

Dyng:
- If resources are not enough
-If they reach the maximun age
-Randomly 30% of birth are discarded
-Randomly 5% of agentes are descarded

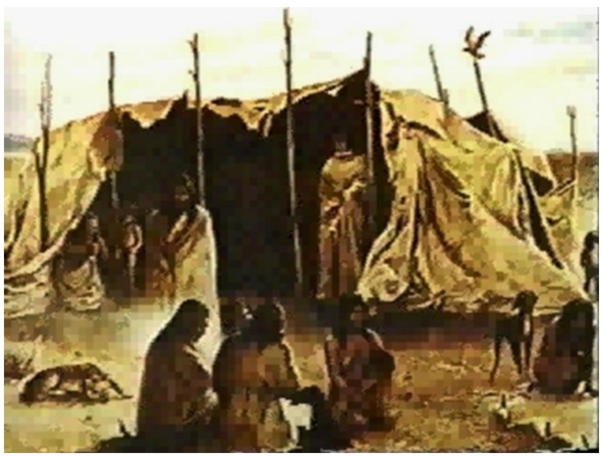
Process Overview. Sequence of

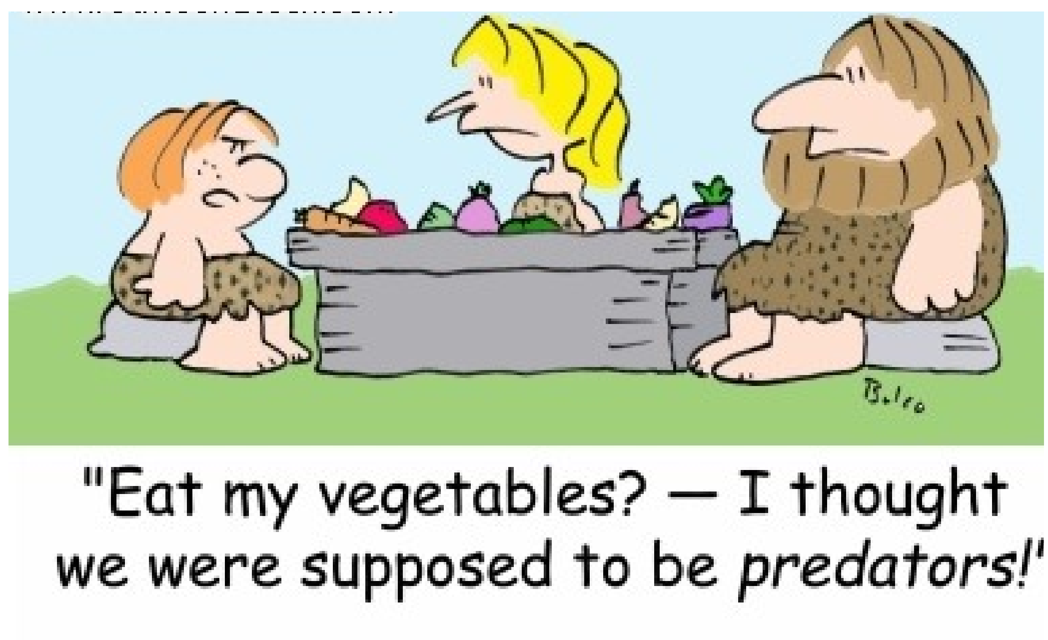


Subprocesses. SURVIVE

SURVIVE: Agents start with enough energy to survive the first time-step. Energy at start-up is calculated as

$$e_i = \bar{e}_i / d_i$$





Subprocesses

```
to survive
  ; harvest and hunting
  ask families [
    let group-capacity ( capacity + sum [ capacity ] of my-group )
    let family-output ( capacity * ( group-capacity  ^ ( returns-to-cooperation - 
1 ) ) )
    set energy ( ( energy * (1 - energy-depreciation) ) - subsistence  + family-
output )
    set energy max (list 0 energy )
 ]
end
```

$$O_j(t) = \frac{c_j}{\sum_{k \in Gj(t)} c_k} \left(\sum_{k \in Gj(t)} c_k \right)^{\theta} = c_j \left(\sum_{k \in Gj(t)} c_k \right)^{\theta - 1} \quad \text{with} \quad \theta \geq 1$$

Subprocesses. SURVIVE

Each agent begins by using existing surplus, produced at the end of the previous time-step. If stored surplus (s_i) is equal to the survival threshold ($\bar{e}_i$), the agent survives. If stored surplus is not enough, the agent should produce food (e_i). After survival, the amount of food that is not consumed is converted into surplus.

Subprocesses.LOOK FOR FOOD

Food is obtained by agent *i* by means of labor ($l_i(t)$) with the contribution of its own technology $b_i(t)$, used to compensate the local difficulty of producing food (h_i). In this simulation, we assume that any individual can produce 360 kilocalories in a single six-months time-step (2000 calories per day * 180 days).

$$e_i = [360\ l_i(t) / h_i\ ] * b_i(t)$$

(h_i) is a Poisson distributed parameter counting the quality of soil and the availability of water and temperature: the poorer quality of soils and the scarcer is water, the more labor or more technology is needed to obtain resources up to survival threshold). This parameter is initiated at start up (a random number following a Poisson distribution whose l is a free parameter selected by the user at the beginning of the simulation), and changes every time-step, in such a way that at odd cycles (warm season) it is the half that at even cycles (cold season).

.

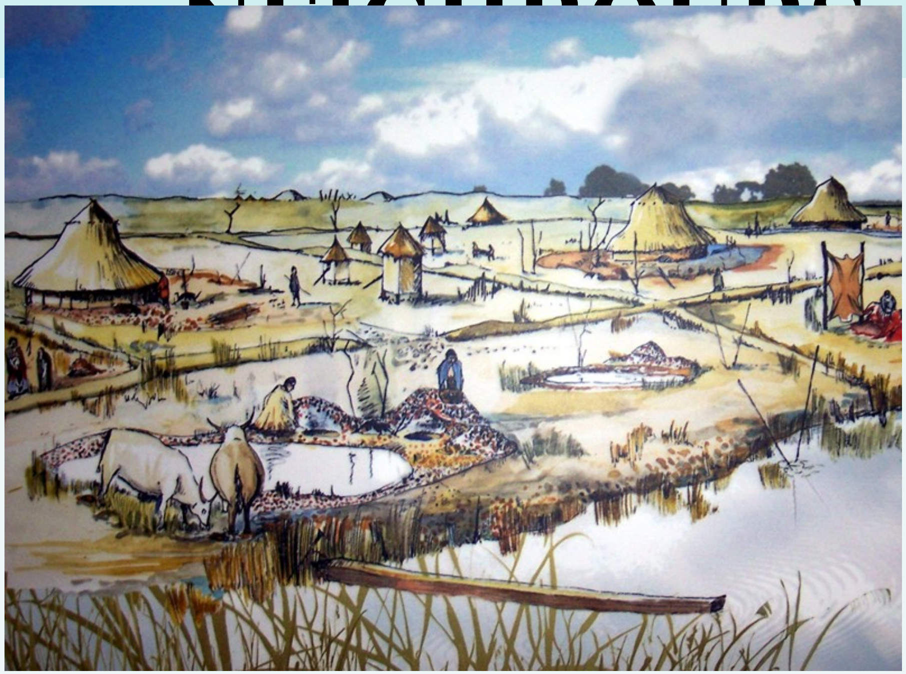
Subprocesses.HUNT-and-GATHER

Energy is obtained by agent *i* by means of labor, with the contribution of its own technology (β).

$$f_i(t) = \frac{1}{1 + \frac{1}{h_i(t) \cdot l_i(t)^{\beta_i(t)}}}$$

This equation measures the ability to obtain resources according to each agent's individual ability.

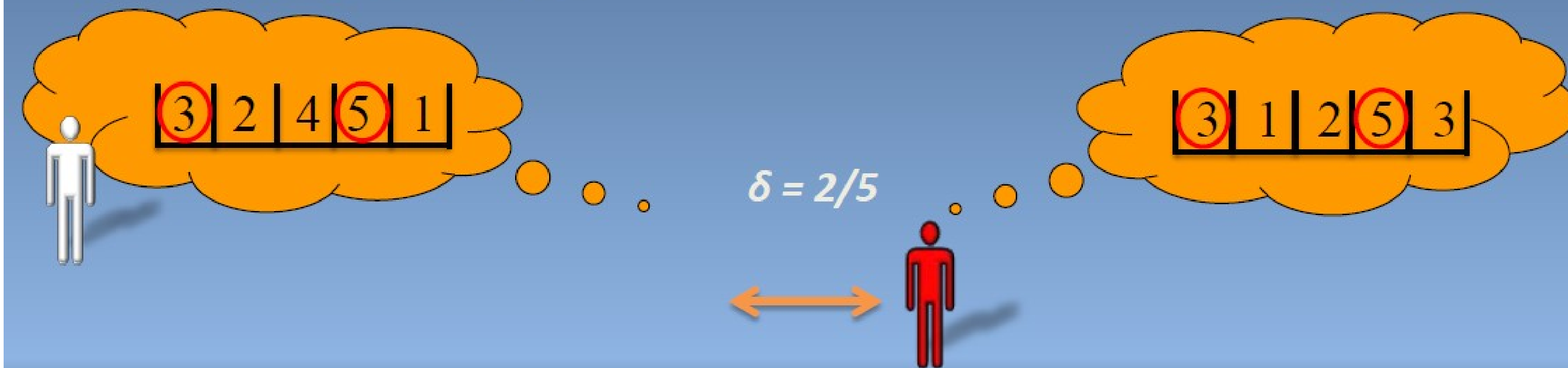
Subprocesses.IDENTIFY-NEIGHBOURS



Many procedures depend on the actual degree of cultural consensus between agents. It is calculated in terms of the similarity between the identity of agents. The identity of an agent is expressed in a binary vector including the presence/absence information of cultural elements, which can be also identified in the archaeological record. Given that each agent is in fact an integration of local groups (archaeological sites: settlements, hillforts, workshops, cemeteries, ritual places, etc.) such a vector contains the statistical mode of all attributes present in the buffer zone corresponding to each “regional” agent.

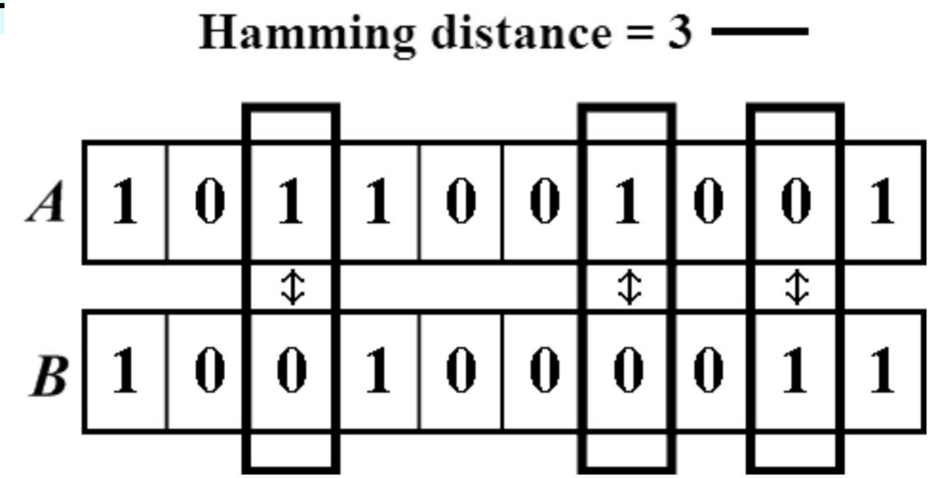
How do the agents interact?:

- Two agents regard themselves similar if they share, at least, a proportion of δ cultural traits (**cultural proximity**)
  - Example: δ = 2/5



We are similar
Let's cooperate!

Subprocesses.IDENTIFY-NEIGHBOURS



When identifying other agents in the area, each agent calculates a Hamming distance between each pair of identity vectors. The Hamming distance between two strings of equal length is the number of positions at which the corresponding symbols are different.

$$d^{HAD}(i,j) = \sum_{k=0}^{n-1} \left[y_{i,k} \neq y_{j,k} \right]$$

In the equation d^{HAD} is the Hamming distance between the objects i and j, k is the index of the respective variable reading y out of the total number of variables n.

Subprocesses.IDENTIFY-NEIGHBOURS

How big should be this threshold to allow cooperation between agents or increase the probabilities of being attacked? If an agent is able to produce enough food by itself and survive, it does not bother to identify other agents in the territory. Otherwise, agents calculate the percentage of consensus needed, depending on how much they need food or tools from others to survive. The greater the ease with which an agent obtains needed resources, the more predisposed to help at no cost. This

$$ST = \frac{1}{100}\left(\left[\frac{\bar{e}_i}{h_i(e_i-\bar{e}_i)}\right]^{1/\beta_i} - l_i\right)$$

A similarity threshold (*ST*) expressing the degree of independence an agent has on others

Subprocesses:RATIONAL DECISSION

If the current measure of identity similarity between agents *i* and *j* is above the calculated value of $ST_{(t)}$ then there is option to decide whether exchange or not, according to expected benefits.

To be rational, the decision whether sending the requested food or refusing the proposed exchange should imply a way to evaluate the advantages or drawbacks of this behavior.

Prisoner's Dilemma

		Region 2 (with food in excess)	
		Exchange	Refuse Exchanging
Region1 (in need)	Exchange	**5, 3**	**0, 5**
	Refuse Exchanging	**5, 0**	**5, 0**

In our case,

Temptation (T) > Reward (R) > Punishment (P) = Sucker (S)

And it is easy to see that

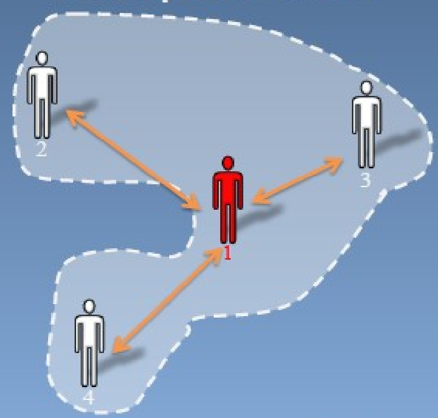
2R > T + S

Consequences of cooperation:

1. **Higher output**: I get more output than if I act individually:
   - Individually:

$$O_j(t) = c_j$$

   - Cooperation:



$$O_j(t) = c_j \left(\sum_{k \in G_j(t)} c_k \right)^{\theta - 1} \quad \text{with } \theta \geq 1$$

Θ: Increasing returns-to-cooperation

Subprocesses. Cooperate

Provided there is enough CULTURAL CONSENSUS, agents who cannot survive on their own are helped by "culturally similar" neighbors with enough amounts of labor and technology

$$\Delta f_i(t) = \frac{1}{1 + \frac{1}{[h_i(t)\cdot(\sum j \in G_i(t) l_j(t)^{\delta\beta_j(t)})^{\theta_i(t)}]}}$$

where $G_i(t)$ is the total amount of labor the group of agents that cooperate with agent i and $\delta\beta_i(t)$ the maximum technology within the group. There is an additional parameter modifying the total effect of aggregated labor at the social aggregate ($\theta_i(t)$), capturing the idea that cooperation is less needed when there are plenty of resources. In other words, it measures the added value that cooperation brings to production returns.

"We are neither hunters nor gatherers. We are accountants."

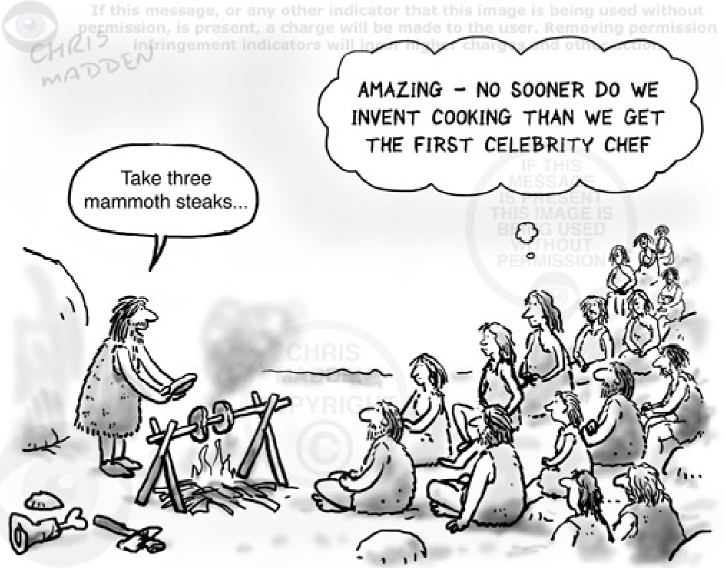
Subprocesses. UPDATE “Culture”

Once the agent gets enough resource for its own survival (with or without the help from others), the identity vector (CULTURE) is updated towards the statistical mode of the groups identity.

With a fixed probability level (95%) each agent copies the statistical mode of identities within the group.

There is an additional source of identity change, implemented in form of an INTERNAL CHANGE RATE (IRC). This is a random value (from 0 to 1, usually very small) defined in analogy to the probabilities of internal change (invention, mutation, catastrophe, sudden change).

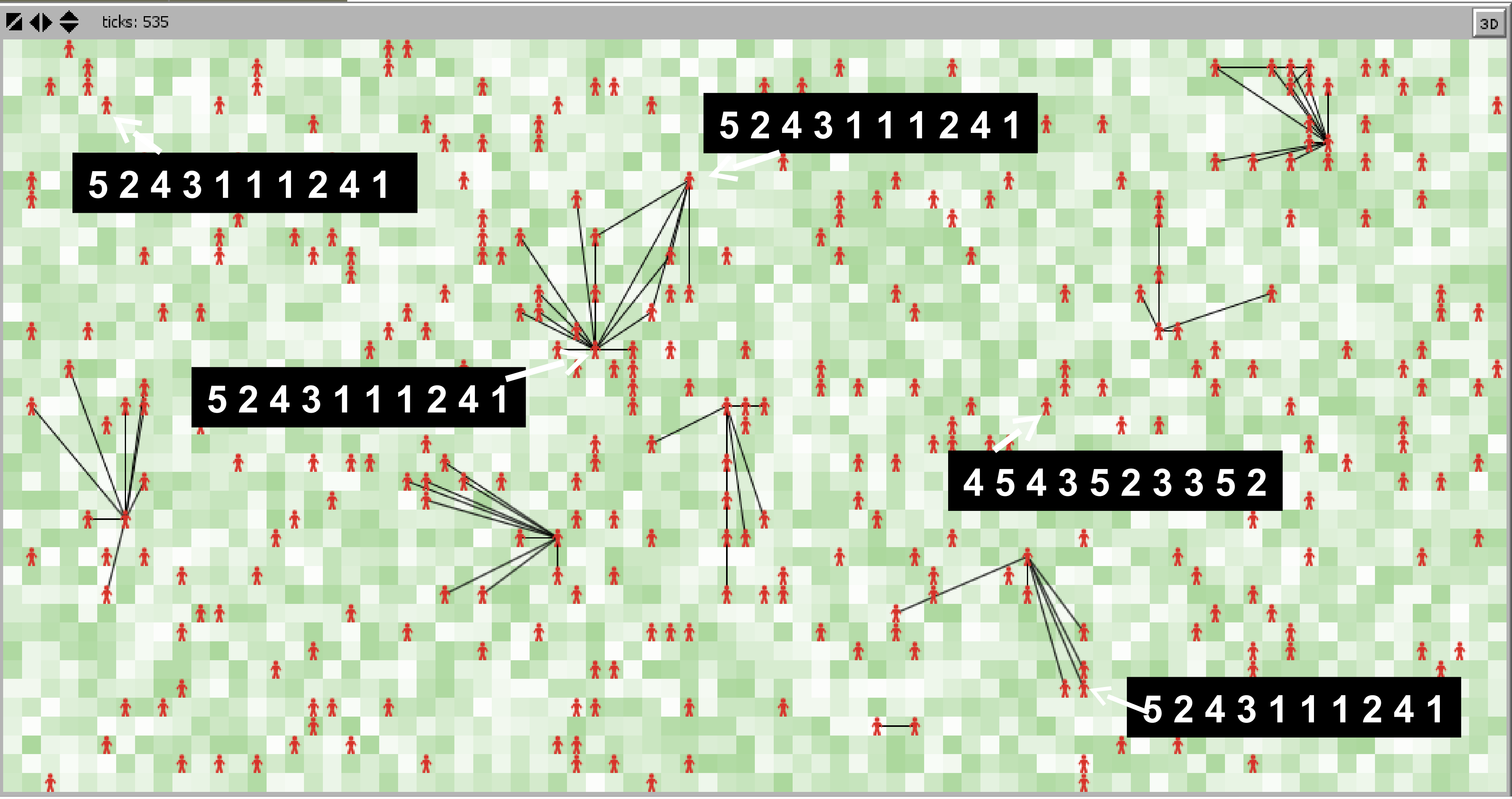
TECHNOLOGY IS ALSO UPDATED IN THE SAME WAY, towards the most efficient value in the emerging aggregate of cooperating agents



Subprocesses

```
to evolve-culture
  ; cultural diffusion process
  ask families [
    if any? my-group [
      let consensual-culture compute-consensual-culture-within-group
      let different-cultural-traits [ ]
      foreach n-values cultural-dimensions [?]
        [ if (item ? culture) != (item ? consensual-culture) [ set different-cultural-traits fput ? different-
cultural-traits ] ]
      if not empty? different-cultural-traits
        [ if (random-float 1 < p-cult-diffusion)
          [ let trait-to-copy one-of different-cultural-traits
            set culture replace-item trait-to-copy culture (item trait-to-copy consensual-culture ) ] ]
    ]
  ]
  ; cultural mutation process
  ask families [
    if random-float 1 < p-cult-mutation
      [  let trait-to-mutate one-of n-values cultural-dimensions [?]
         let new-trait random cultural-traits
         set culture replace-item trait-to-mutate culture new-trait
         ask my-group [ set culture replace-item trait-to-mutate culture new-trait ]
      ]

end
```

Subprocesses.CULTURAL CONSENSUS



Identity comparison after 652 ticks

Subprocesses. REPRODUCE

Agents lose one of its members (a labor unit) each time the total acquired energy is below survival threshold. In the same way, every 30 ticks, a new member is born, and it will be alive until total acquired energy is below survival threshold. In this way, we have implemented a determinist population growth mechanism opposed to stochastic mortality.

Subprocesses

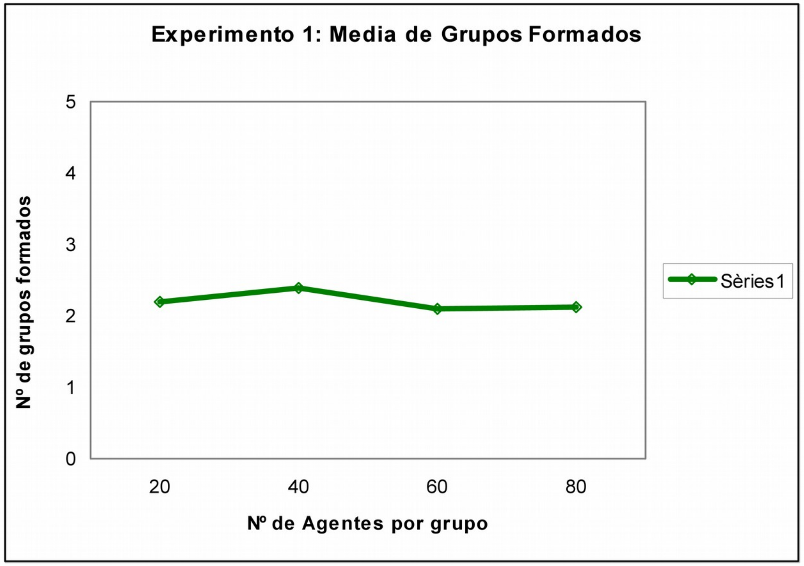
```
to replace

  ; Replacements uses a roulette wheel rule according to families' capacities
  ; oldage deaths
  let oldage-deaths [ ]
  ask families [
     set age ( age + 0.5)
     if ( age >= max-age ) [ set oldage-deaths (fput who oldage-deaths) ]
   ]
  ; new families
  let parents descendant-parents length oldage-deaths
  foreach parents [ new-descendant ? ]
  foreach oldage-deaths [  ask family ? [ die ] ]
  set n-deaths-by-old-age (length oldage-deaths)
  ; starving deaths
  let starving-deaths [ ]
  ask families [
     ifelse ( energy <= 0.01 )
       [ set periods-without-energy (periods-without-energy + 1)]
       [ set periods-without-energy 0 ]
     if ( periods-without-energy > max-periods-without-energy) [ set starving-deaths (fput who starving-deaths) ]
   ]
  foreach starving-deaths [  ask family ? [ die ] ]
  set n-deaths-by-insufficient-energy (length starving-deaths)
  set parents descendant-parents length starving-deaths
  foreach parents [ new-descendant ? ]
End
to new-descendant [ parent-who ]
  ask family parent-who
      [  hatch 1 [
           set age 0
           set max-age random-poisson life-expectancy
           set capacity random-float 1
           set-neighborhood-and-group ]
      ]
end
```

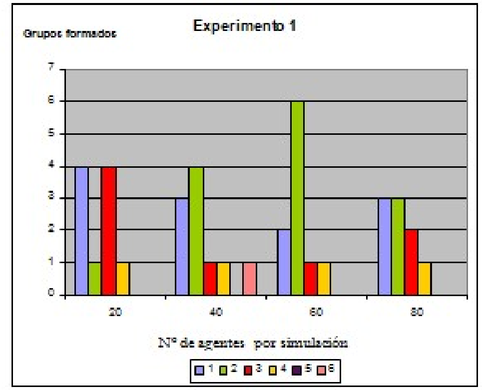
Experimental Results

Scenario 1 →	Controlled Variable: **Population**
Scenario 2 →	Controlled Variable: **Cooperation Advantages**
Scenario 3 →	Controlled Variable: **Cultural Dimensions**
Scenario 4 →	Controlled Variable: **Tollerance to others difference**
Scenario 5 →	Controlled Variable: **Size of Mobility Neighbourhood Area**

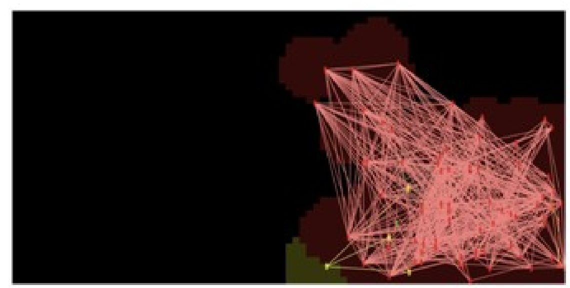
Scenario 1

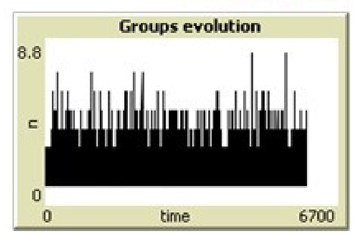
Controlled Variable: **Population**





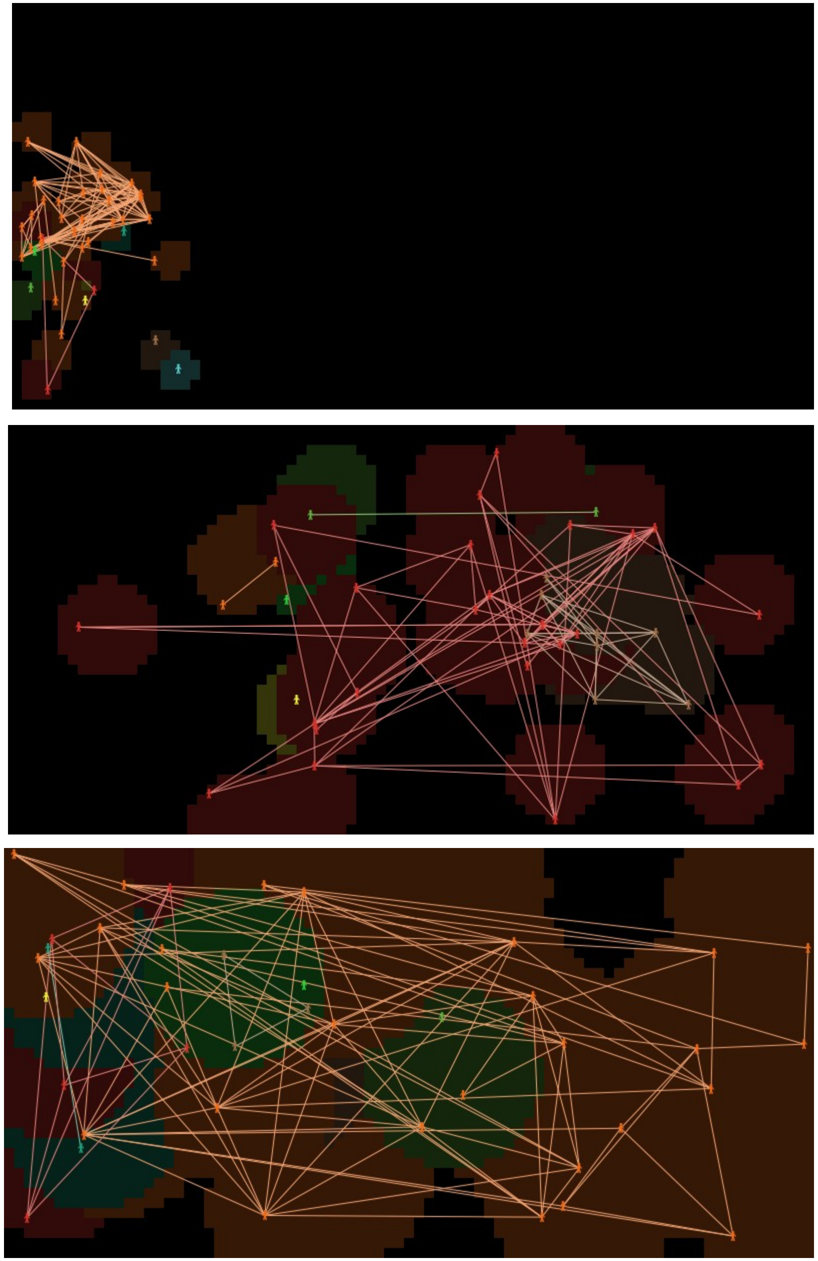
Pantalla 2: El gráfico indica el número de grupos que se han formado en 10 simulaciones con números diferentes de unidades familiares o agentes [20 40 60 80].

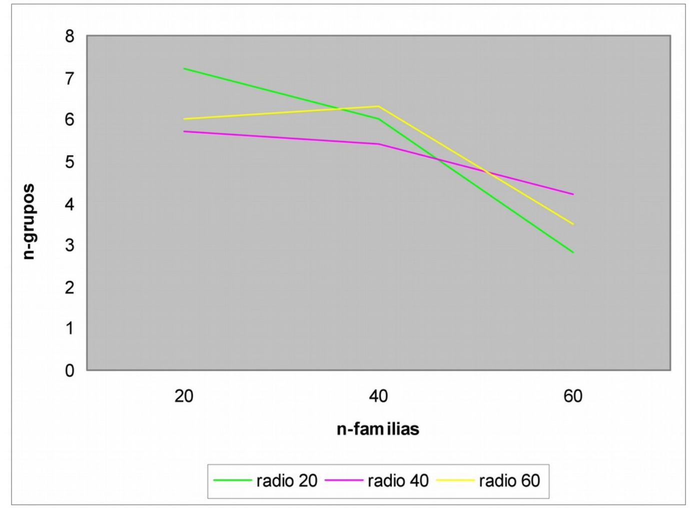


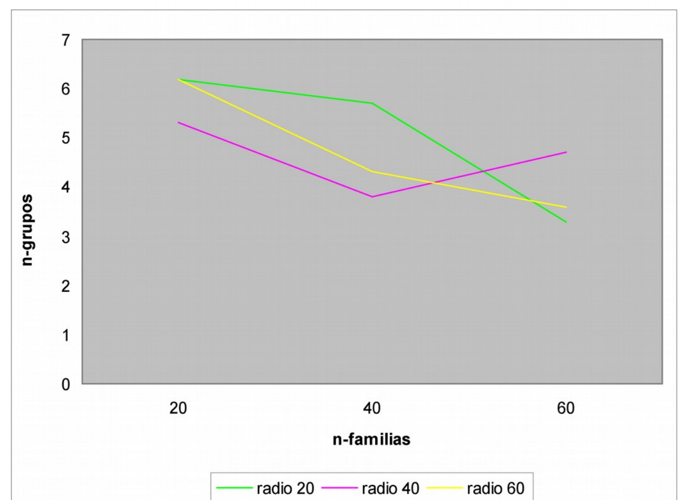


Scenario 2

Controlled Variable: **Size of Mobility Neighbourhood Area**

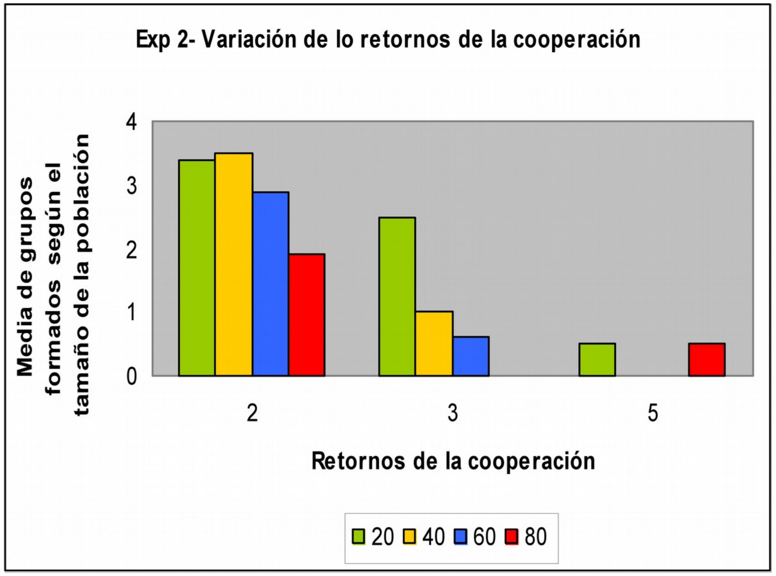


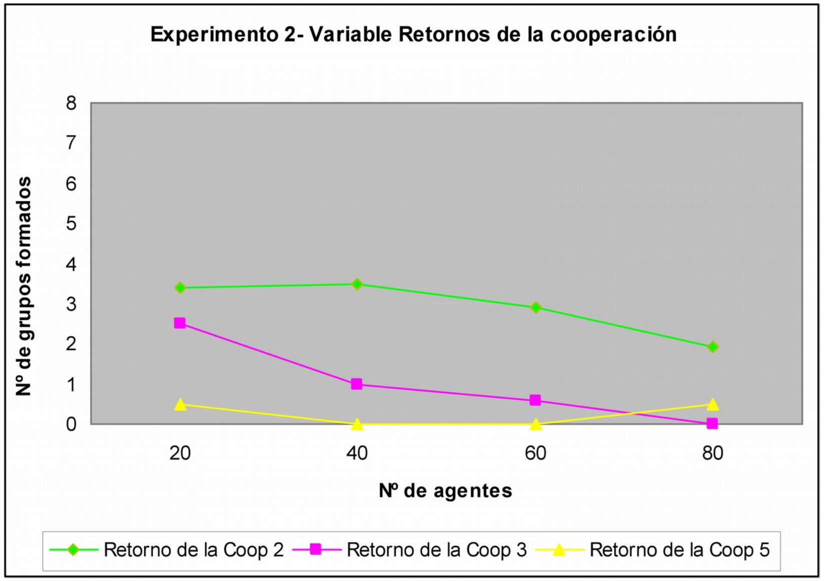


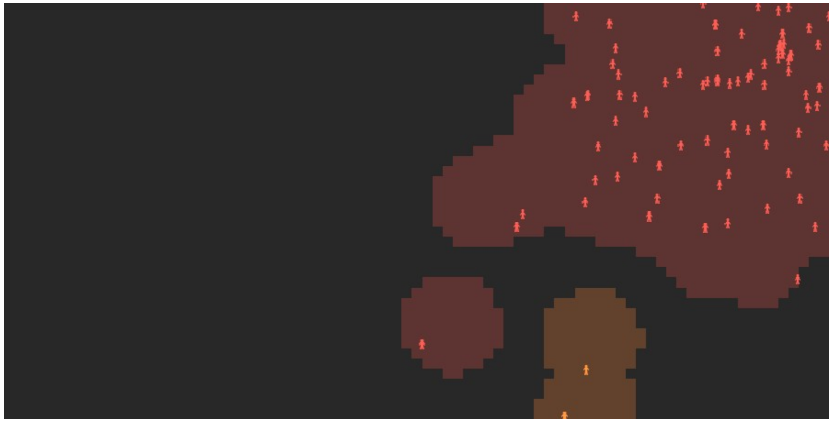


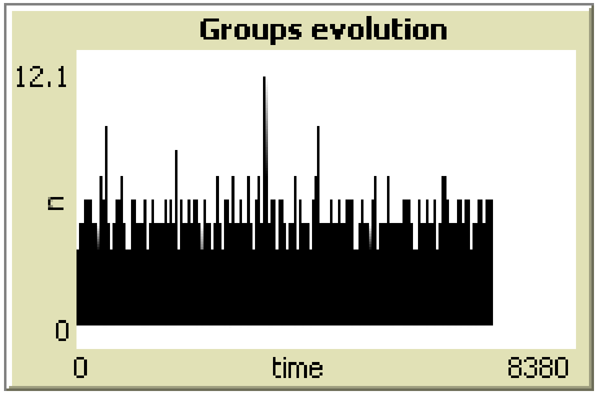
Scenario 3

Controlled Variable: **Cooperation Advantages**

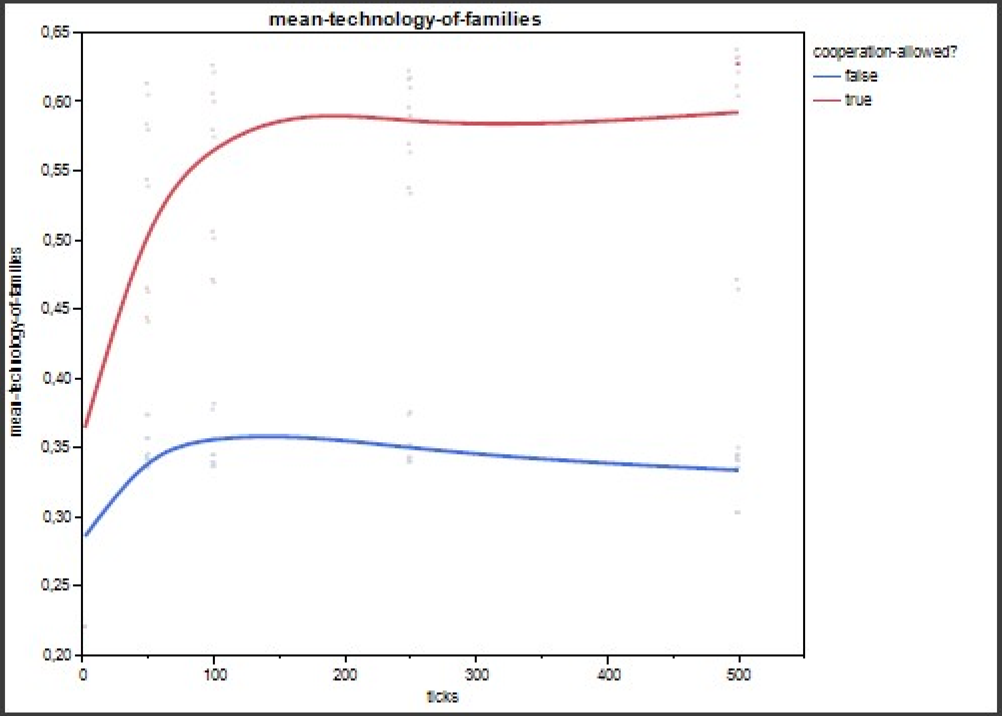








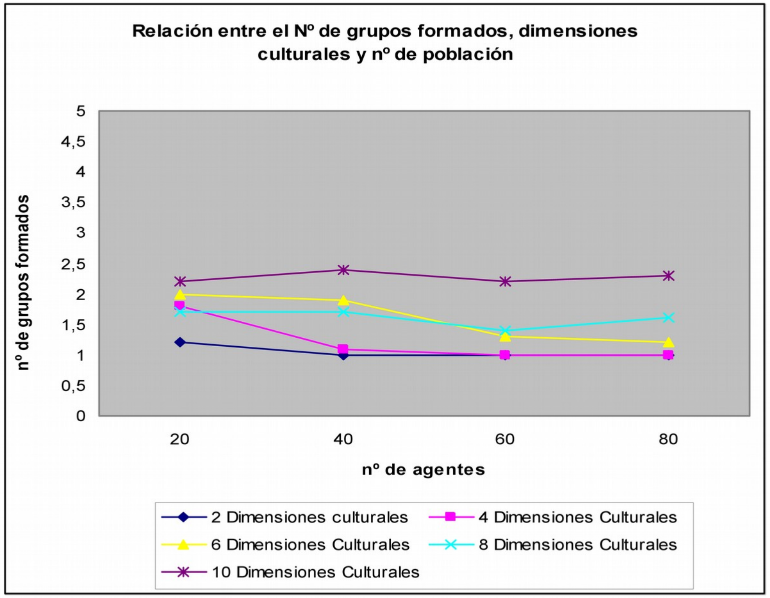
The consequences of cooperation: diffusion of technological innovations.

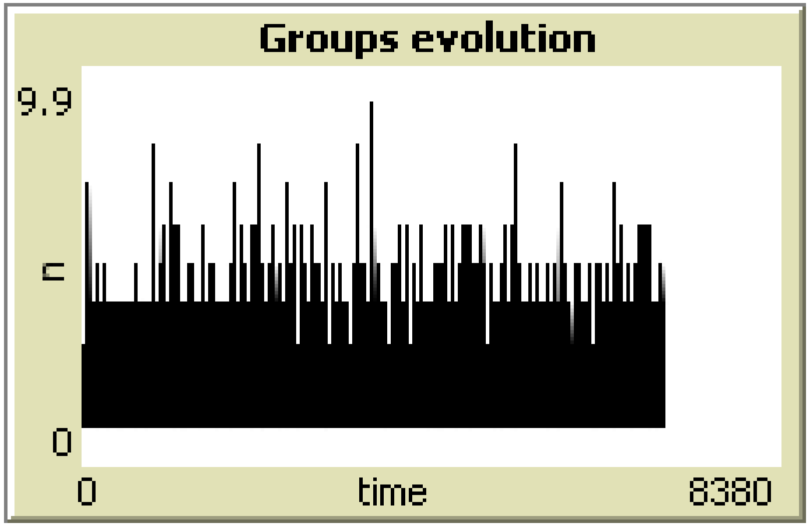


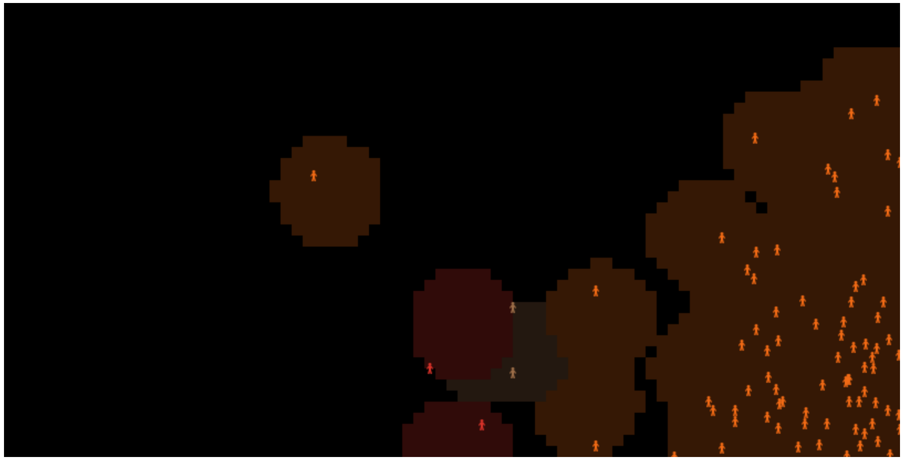
In the cooperation scenario, average-technology quickly evolves to higher values. The difference of means is statistically relevant. In the non-cooperative scenario, agents are also very different in their technological efficiency, while cooperation generates scenarios of more homogenous diffusion

Scenario 4

Controlled Variable: **Identity**

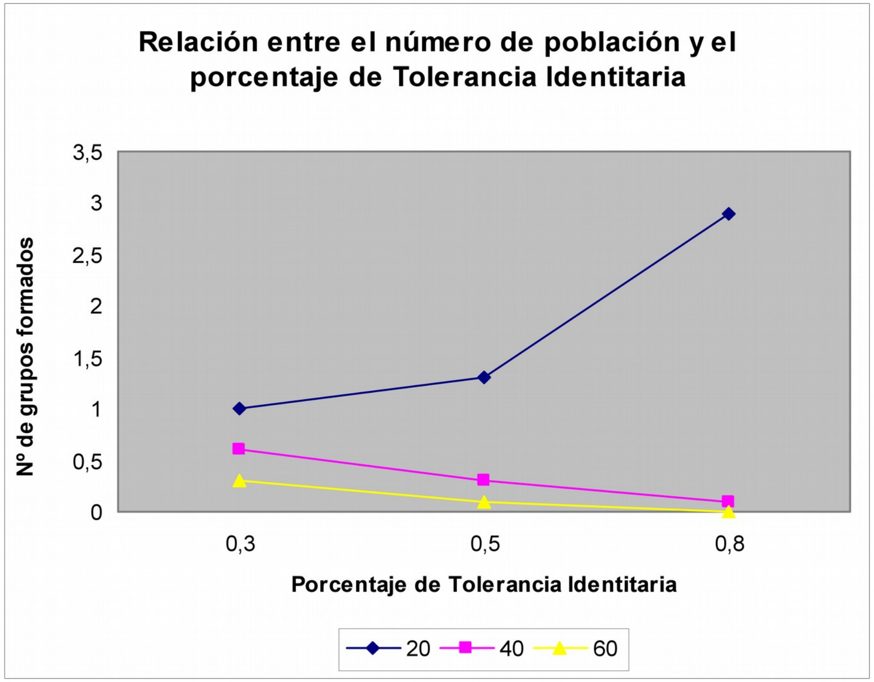


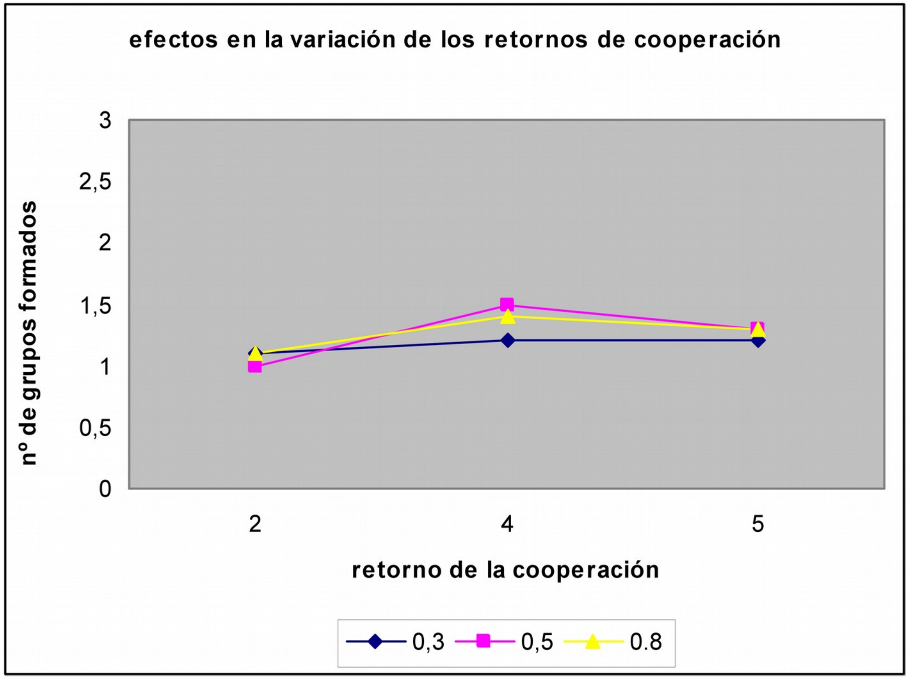




Scenario 5

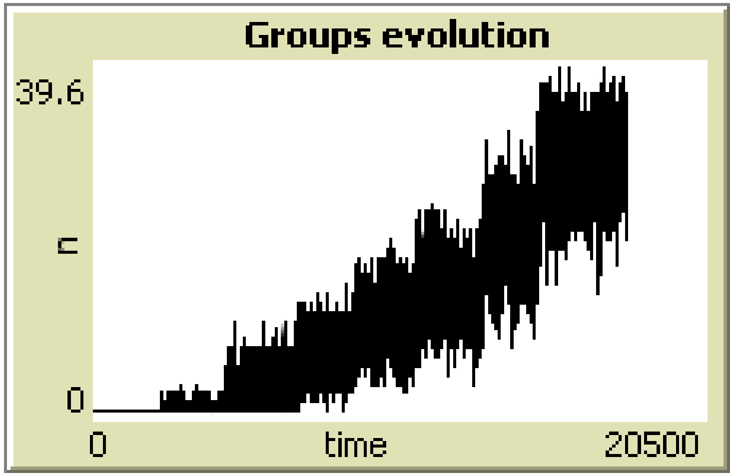
Controlled Variable:
Intolerance to others difference

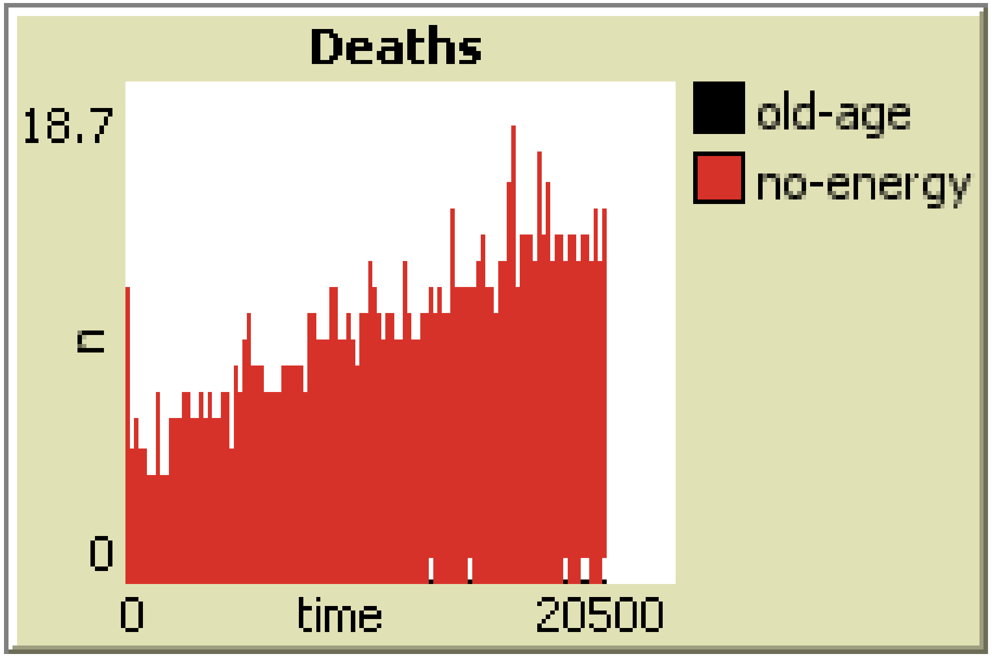


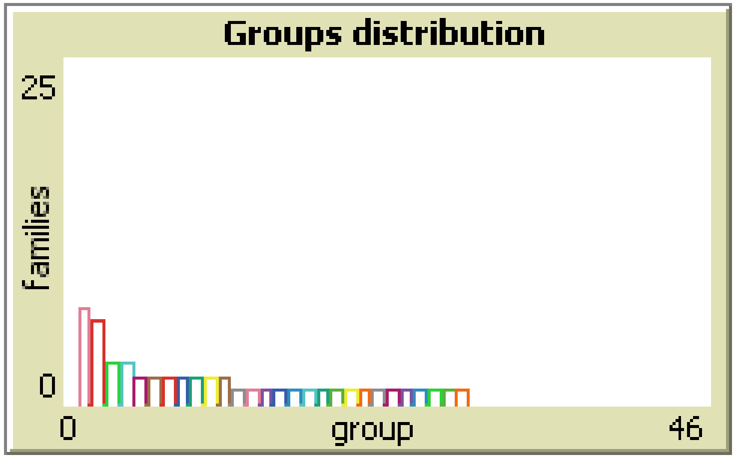


Scenario 5

Controlled Variable:
Intolerance to others difference

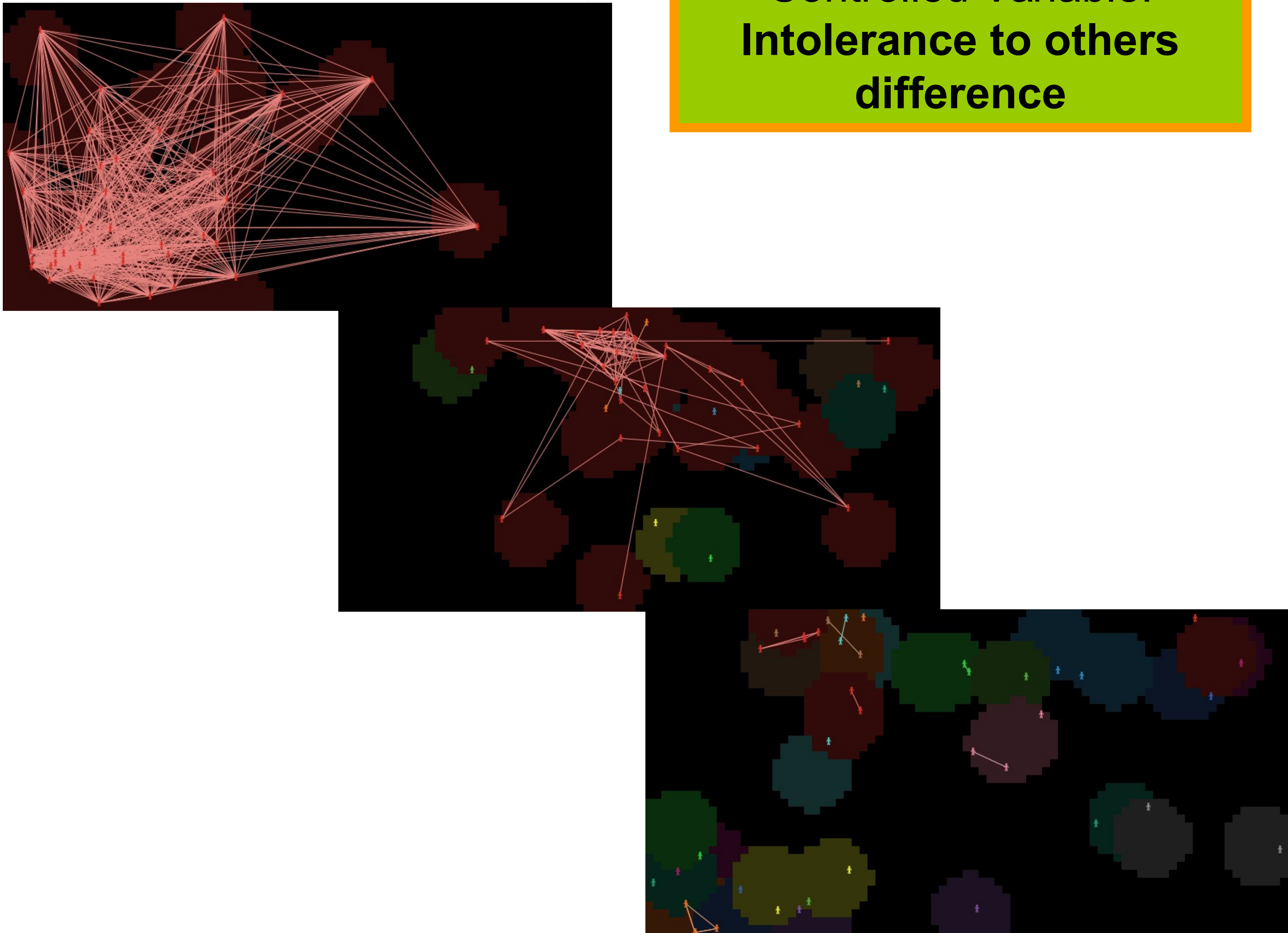




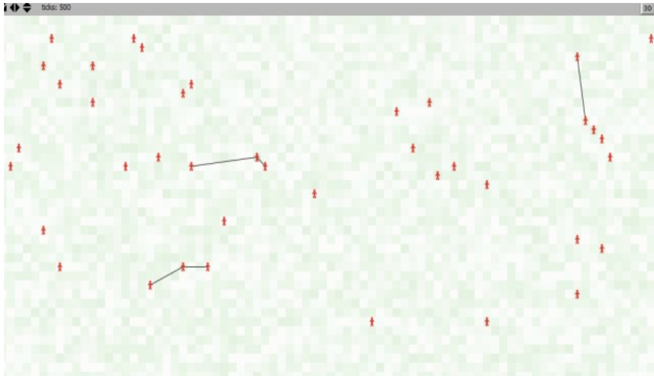


Scenario 5

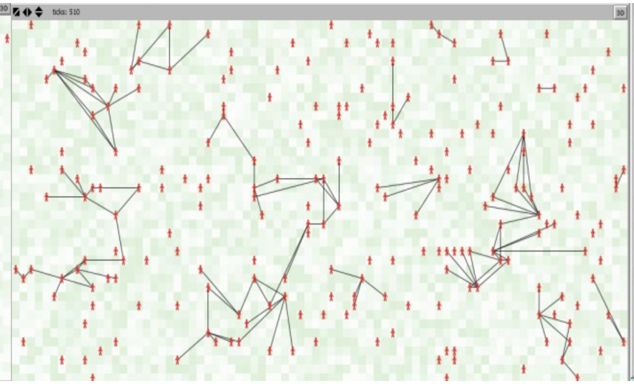
Controlled Variable:
Intolerance to others difference



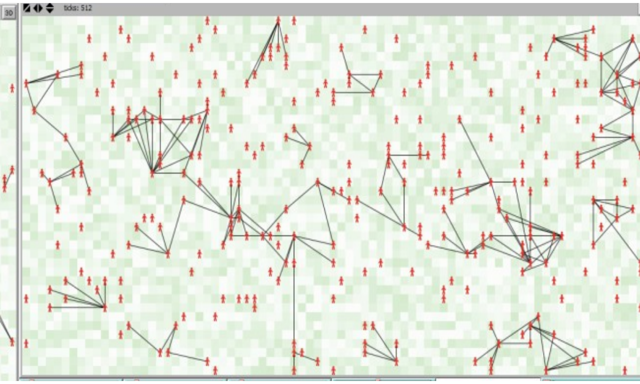
The consequences of cooperation: social aggregation.



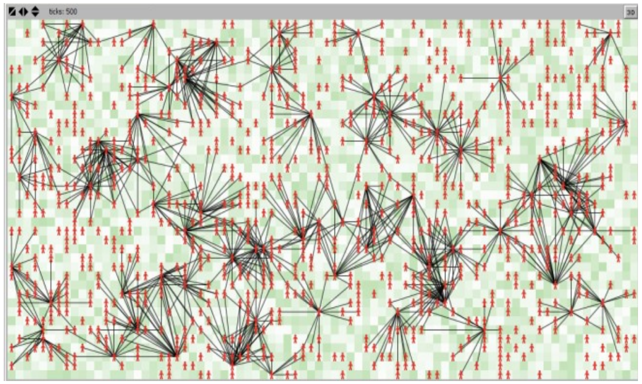
Max. Resources 15000.



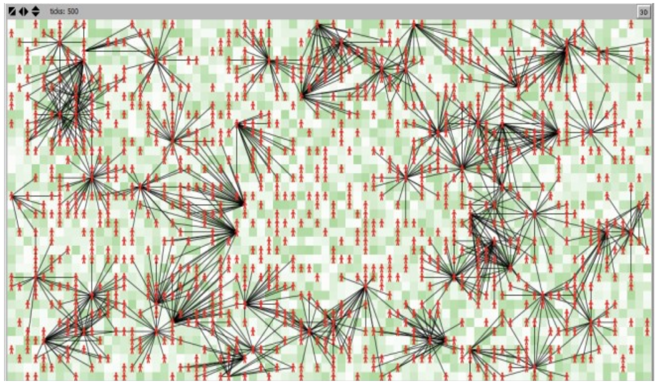
Max. Resources 20000.



Max. Resources 25000.



Max. Resources 40000.



Max. Resources 50000.

The consequences of cooperation: social aggregation.

Fractionalization,
Herfindhal Concentration Index

$$ELF_j = 1 - \sum_{i=1}^{I_j} \left(\frac{n_{ij}}{N_j}\right)^2 = 1 - \sum_{i=1}^{I_j} s_{ij}^2 \qquad i = 1, \ldots, I_j$$

	Scenario 1 Poor resources	Scenario 2	Scenario 3	Scenario 4	Scenario 5 Abundant resources
ELF	0.9863	0.92	0.97	0.423	0.431

The consequences of cooperation: social aggregation.

Generalized Resemblance

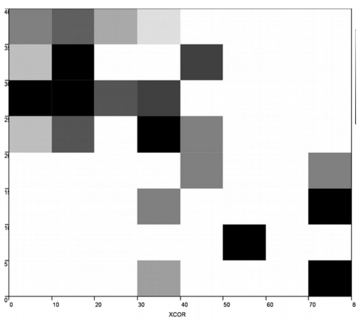
Bossert et al. Ethno-Linguistic Fragmentation

$$G(S_N) = 1 - \frac{1}{N^2}\sum_{i=1}^{N}\sum_{j=1}^{N} s_{ij}$$

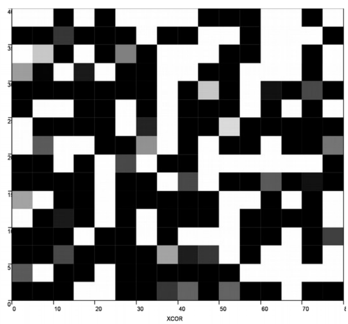
	Scenario 1 Poor resources	Scenario 2	Scenario 3	Scenario 4	Scenario 5 Abundant resources
$G(S_N)$	4.96	0.86	0.06	0.115	0.144

The consequences of cooperation: social aggregation.

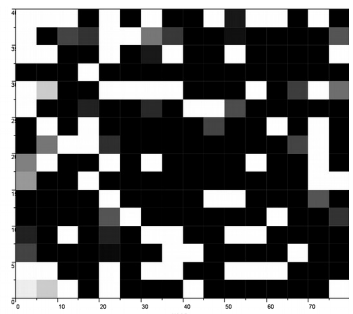
Generalized Resemblance



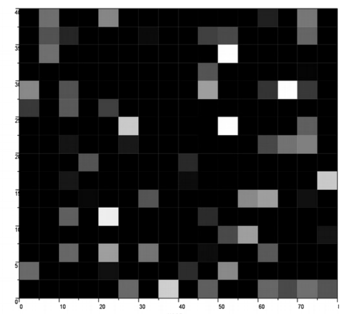
Resources 15000



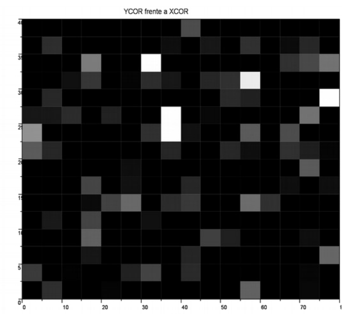
Resources 20000



Resources 25000



Resources 40000



Resources 50000

The consequences of cooperation: social aggregation.

Demographic polarity

Montalvo and Reynal-Querol Index

$$RQ = 4\sum_{i=1}^{k}\sum_{j\neq i} p_i^2 p_j = 4\sum_{i=1}^{k} p_i^2(1-p_i) = 1 - \sum_{i=1}^{k}\left(\frac{0.5-p_i}{0.5}\right)^2 p_i.$$

	Scenario 1 Poor Resources	Scenario 2	Scenario 3	Scenario 4	Scenario 5 Abundant Resources
RQ	0.0511	0.14	0.09	0.56	0.56

STATED EFFECTS OF THE SOCIAL AGGREGATION

- High benefits of cooperation, since the households will cooperate with a major quantity of households.

- Low levels of tolerance. Households interact less with those households with a minor number of common identity features.

- Emerge in territorial areas with higher numbers of households and/or a higher density of population provided tolerance levels to other difference remain relatively low.

- The higher the cultural resemblance and proximity

- The higher the size of the neighborhood and the size of the population

STATED EFFECTS OF THE SOCIAL SEGREGATION

- Less benefits of labor cooperation. If the interaction between households does not generate a progress in the probabilities of survival, households will survive isolated, without any convergence in their vectors of identity.

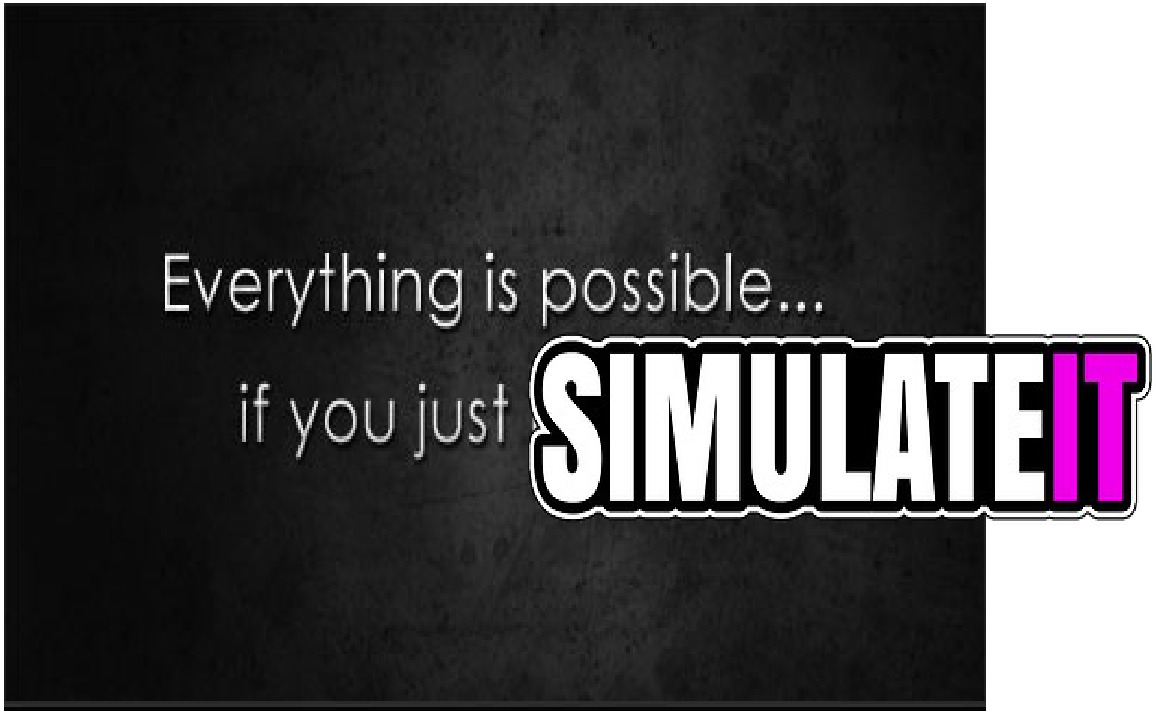
- Low density of population and low intolerance, given the low probabilities of social interaction and labor cooperation.

- Even in case tolerance to others difference be low, households tend to fusion their identities when the number of shared dimensions overcomes 50 %.

- Abundant resources and a high level of intolerance, households segregate easily.

- When the size of neighborhood area increases, and the level of intolerance overcomes a threshold of 50 %-60 %, prior aggregations tend to split.

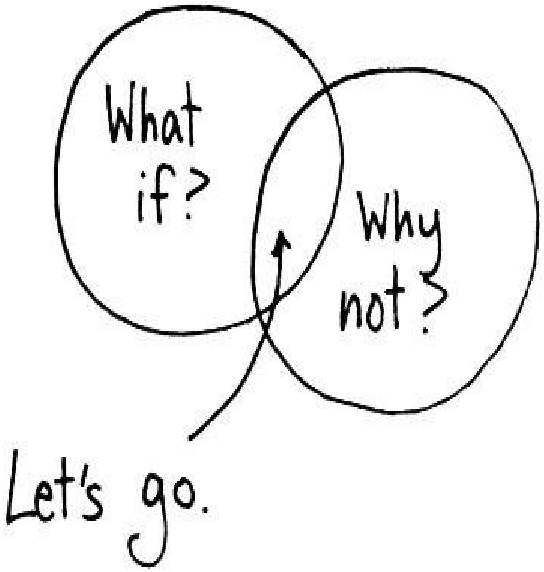
- When the conditions of subsistence deteriorate (resources diminish and the probabilities for survival also decrease) prior aggregations tend to split.



Not everything is possible in a simulated world

What is possible within the model?

Sensitivity Analysis



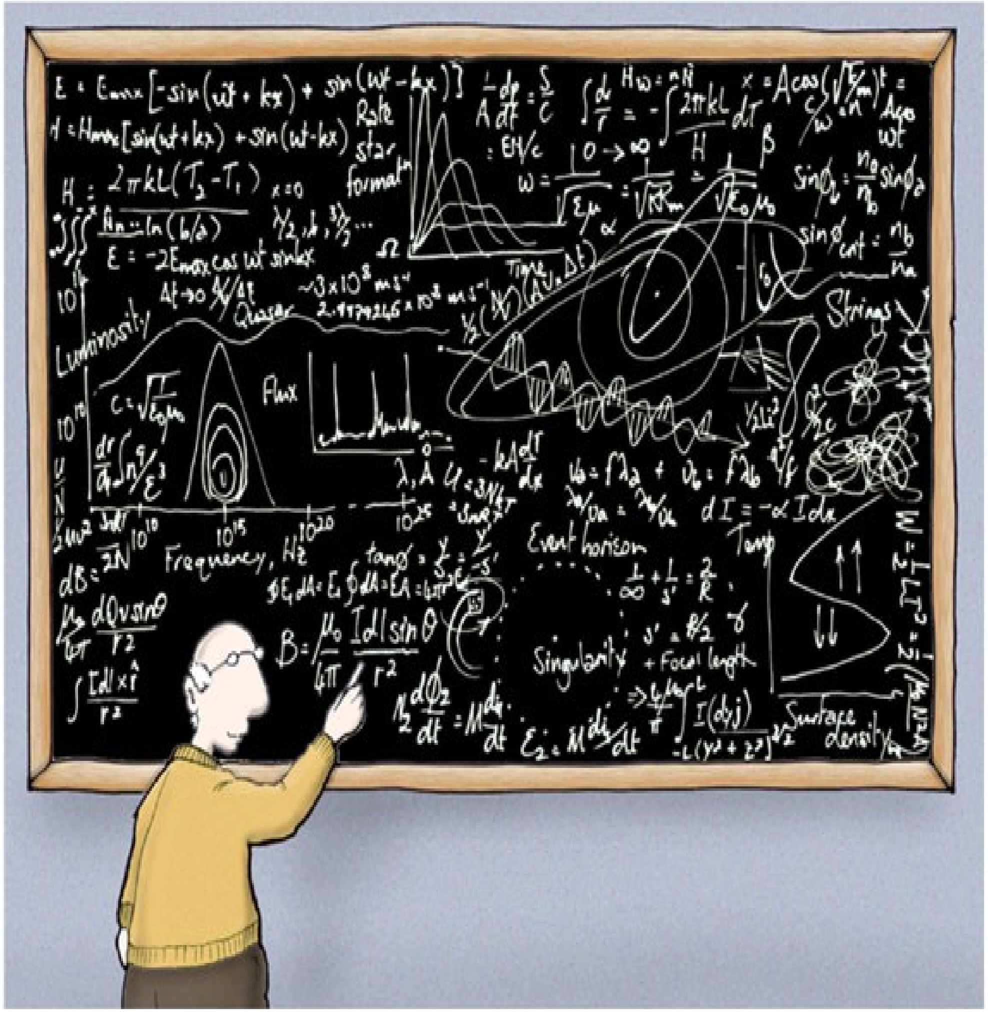
Sensitivity analysis: Ensuring that the model produces reasonable results when factors and assumptions are changed

We need to test the behavior and response of the model when modifying in a directed way various assumptions and factors

.

What is possible within the model?

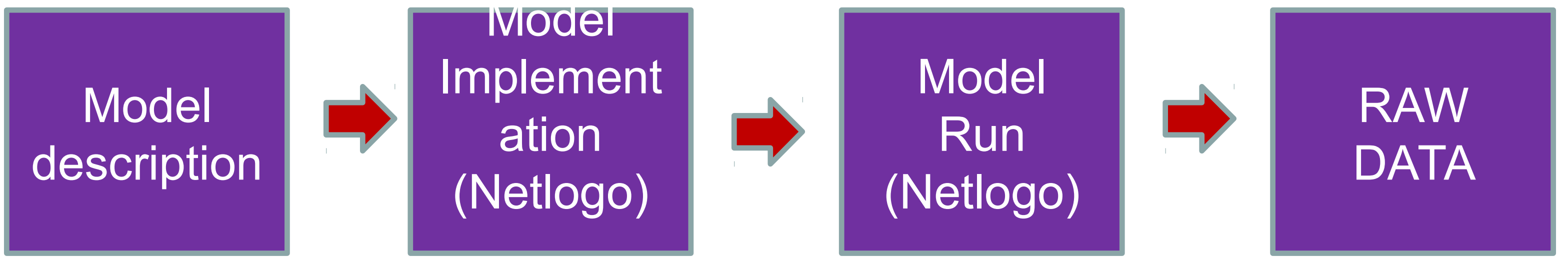
Exploring the Parametric Space



In sensitivity analysis, the number of factors should be kept as low as possible. But this

What is possible within the model?

Exploring the Parametric Space

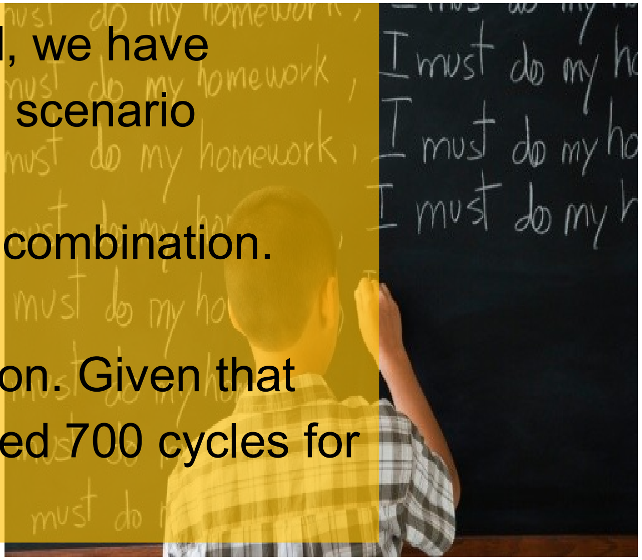


What is possible within the model?

Exploring the Parametric Space

For each value of N (=10, 100, 200, 400),
a repetition has 3x4x3x3x3x4x3= 3888 runs (parameter combination),
each one stops after 700 ticks.

What is possible within the model?
Exploring the Parametric Space

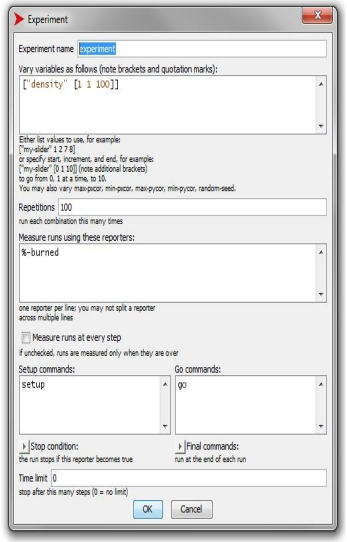


- Because of the intrinsic stochasticity of the model, we have executed repeated number of times each posible scenario
- We have made 30 runs para for each parametric combination.
- Each run simulates 350 years of historical evolution. Given that each cycle represents a season, we have executed 700 cycles for each run.

What is possible within the model?

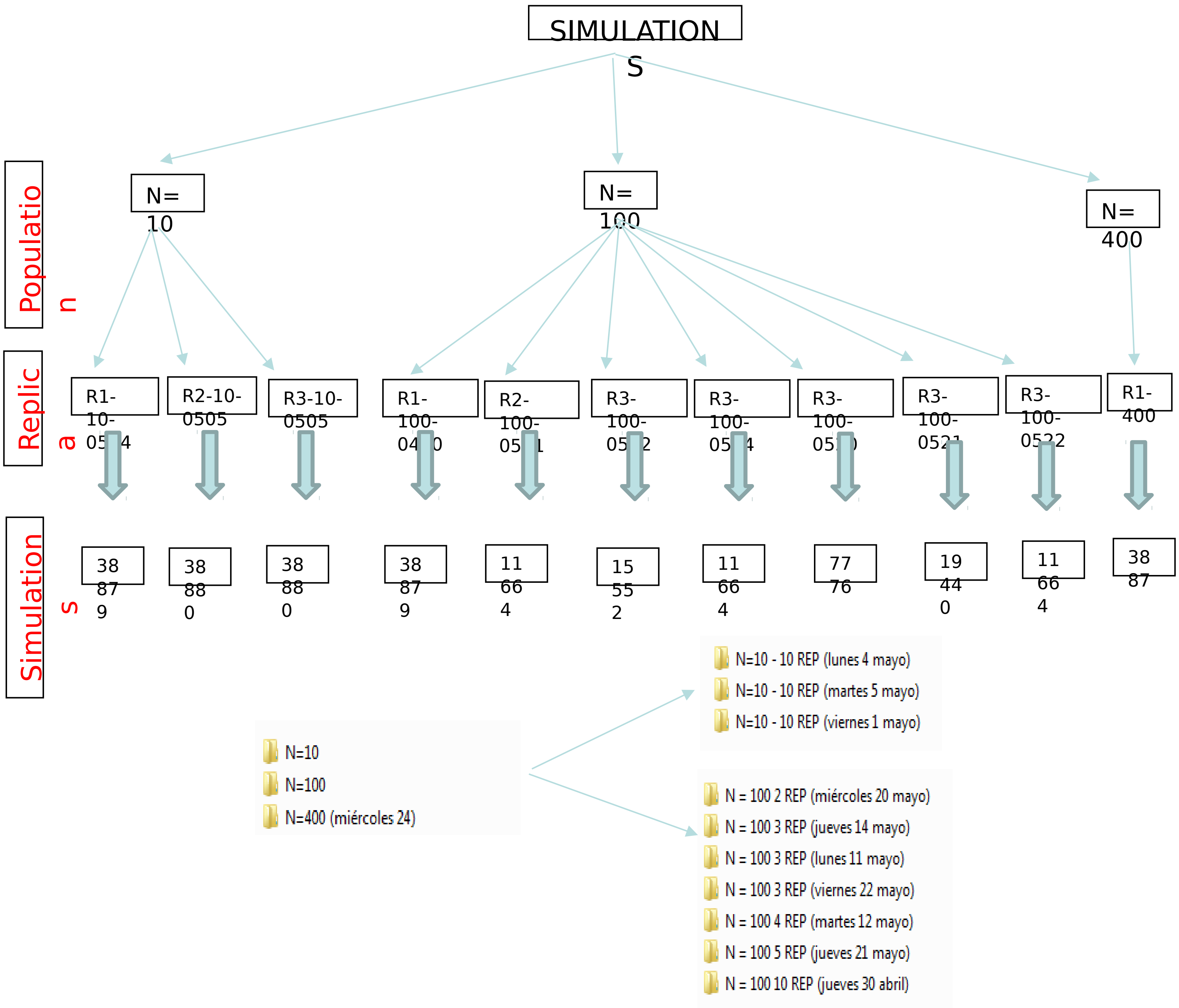
Exploring the Parametric Space

NetLogo BehavioralSpace



Simulated Population	Computer Run Time (each 10 repetitions)
N = 10	12 hours
N = 100	6-7 days
N = 200	34 hours (each repetition)
N = 400	55 horas (each repetition)

Primitively Simple Grid Computing


SIMULATIONS
Population
Replica
Simulations
N=10
N=100
N=400
R1-10-
R2-10-0505
R3-10-0505
R1-100-
R2-100-
R3-100-
R3-100-
R3-100-
R3-100-0521
R3-100-0522
R1-400
38879
38880
38880
38879
11664
15552
11664
7776
19440
11664
3887
N=10 - 10 REP (lunes 4 mayo)
N=10 - 10 REP (martes 5 mayo)
N=10 - 10 REP (viernes 1 mayo)
N=10
N=100
N=400 (miércoles 24)
N = 100 2 REP (miércoles 20 mayo)
N = 100 3 REP (jueves 14 mayo)
N = 100 3 REP (lunes 11 mayo)
N = 100 3 REP (viernes 22 mayo)
N = 100 4 REP (martes 12 mayo)
N = 100 5 REP (jueves 21 mayo)
N = 100 10 REP (jueves 30 abril)

What is possible within the model?

Exploring the Parametric Space

For each run the simulation generates 4 files:

ARCHIVOS AGENTS

IUE
ticks
who
xcor
ycor
collected-energy
total-energy
labor
survival-threshold
technology
storing-factor
individual-capability
similarity-threshold
cooperation?
my-superagent
identity [0]
identity [1]
identity [2]
identity [3]
identity [4]
identity [5]
identity [6]
identity [7]
identity [8]
identity [9]

ARCHIVOS OUTPUT

IUE
ticks
number-of-family-deaths-this-tick
number-of-labor-units-deaths-this-tick
number-of-movements

ARCHIVOS SUPERAGENT

IUE
ticks
who
initial-tick
final-tick
max-number-of-members
group-consensual-identity [0]
group-consensual-identity [1]
group-consensual-identity [2]
group-consensual-identity [3]
group-consensual-identity [4]
group-consensual-identity [5]
group-consensual-identity [6]
group-consensual-identity [7]
group-consensual-identity [8]
group-consensual-identity [9]

PARAMETERS

IUE:
cooperation-allowed?
help-limited-to-spare-labor?
initial-population
mean-resource-on-patches
sd-resource-on-patches
average-technology
diversity
labor-average
average-storing-factor
movement
internal-change-rate

What is possible within the model?
Exploring the Parametric Space

General Structure of the Agent File: each record is a description of each a

IUE	ticks	who	xcor	ycor	collected-energy	total-energy	labor	survival-threshold	technology	storing-factor	individual-capability	similarity-threshold	cooperation?	my-superagent	identity [0]
1E+08	0	9	56	12	0	3285.5	9	3285	1	0.5	0.78	0	false	0	4
1E+08	0	5	63	20	0	1460.5	4	1460	1	0.5	0.648	0	false	0	4
1E+08	0	3	28	28	0	1095.5	3	1095	1	0.5	0.482	0	false	0	4
1E+08	0	0	72	39	0	2190.5	6	2190	1	0.5	0.634	0	false	0	4
1E+08	0	2	8	17	0	1825.5	5	1825	1	0.5	0.677	0	false	0	4
1E+08	0	8	36	13	0	2920.5	8	2920	1	0.5	0.696	0	false	0	4
1E+08	0	6	23	14	0	2555.5	7	2555	1	0.5	0.638	0	false	0	4
1E+08	0	7	18	1	0	1825.5	5	1825	1	0.5	0.394	0	false	0	4
1E+08	0	4	43	9	0	730.5	2	730	1	0.5	0.424	0	false	0	4
1E+08	0	1	46	36	0	2190.5	6	2190	1	0.5	0.73	0	false	0	4
1E+08	1	5	63	20	1459.75	1460	4	1460	1	0.5	0.695	0	true	10	4
1E+08	1	2	8	17	1824.75	1825	5	1825	1	0.5	0.71	0	true	10	4
1E+08	1	9	56	12	3284.75	3285	9	3285	1	0.5	0.848	0	true	10	4
1E+08	1	6	23	14	2554.75	2555	7	2555	1	0.5	0.811	0	true	10	4
1E+08	1	1	46	36	2189.75	2190	6	2190	1	0.5	0.853	0	true	10	4
1E+08	1	3	28	28	2.149	215	3	1095	1	0.5	0.029	0,1	true	10	4
1E+08	1	4	43	9	729.75	730	2	730	1	0.5	0.392	0	true	10	4
1E+08	1	7	18	1	1824.75	1825	5	1825	1	0.5	0.744	0	true	10	4
1E+08	1	0	72	39	2189.75	2190	6	2190	1	0.5	0.797	0	true	10	4
1E+08	1	8	36	13	2919.75	2920	8	2920	1	0.5	0.872	0	true	10	4
1E+08	2	1	46	36	2190	2190	6	2190	1	0.5	0.73	0	false	10	4
1E+08	2	9	56	12	3285	3285	9	3285	1	0.5	0.78	0	false	10	4
1E+08	2	4	43	9	730	730	2	730	1	0.5	0.424	0	false	10	4
1E+08	2	3	22	2	568	1095	3	1095	1	0.5	0.544	0	false	10	4
1E+08	2	0	72	39	2190	2190	6	2190	1	0.5	0.634	0	false	10	4
1E+08	2	6	23	14	2555	2555	7	2555	1	0.5	0.638	0	false	10	4
1E+08	2	8	36	13	2920	2920	8	2920	1	0.5	0.696	0	false	10	4

What is possible within the model?

Exploring the Parametric Space

General Structure of the Output File: Each record is a description of an individual tick fron
of living agents and an average number of moving agents has been recorded.

	ticks	number-of-family-deaths-this-tick	number-of-labor-units-deaths-this-tick	number-of-movements
100006656	0	0	0	0
100006656	1	0	0	1
100006656	2	0	0	0
100006656	3	0	0	1
100006656	4	0	0	1
100006656	5	0	0	0
100006656	6	0	0	0
100006656	7	0	0	1
100006656	8	0	0	0
100006656	9	0	0	0
100006656	10	0	0	0
100006656	11	0	0	0
100006656	12	0	0	1
100006656	13	0	0	0
100006656	14	0	0	0
100006656	15	0	0	0
100006656	16	0	0	0
100006656	17	0	0	0
100006656	18	0	0	2
100006656	19	0	0	1
100006656	20	0	0	0

What is possible within the model?

Exploring the Parametric Space

General Structure of the SuperAgent File: each record is a descriptior
a particular moment of time (tick) for each run

IUE	ticks	who	initial-tick	final-tick	max-number-of-members	group-consensual-identity [0]	group-consensual-identity [1]	group-consensual-identity [2]	group-consensual-identi
1E+08	1	10	1	0	10	4	3	1	
1E+08	2	10	1	2	10	4	3	1	
1E+08	3	11	3	0	10	4	3	1	
1E+08	4	11	3	4	10	4	3	1	
1E+08	59	13	59	0	11	4	3	1	
1E+08	60	13	59	60	11	4	3	1	
1E+08	87	15	87	0	12	4	3	1	
1E+08	88	15	87	88	12	4	3	1	
1E+08	131	19	131	0	15	4	3	1	
1E+08	132	19	131	132	15	4	3	1	
1E+08	133	20	133	0	15	4	3	1	
1E+08	134	20	133	134	15	4	3	1	
1E+08	137	21	137	0	15	4	3	1	
1E+08	138	21	137	138	15	4	3	1	

What is possible within the model?
Big Data or "a lot of" Data

**We assume the size of the population at the beginning of the simulation is the para
the degree and nature of Cultural Diversity at the end of the simulation**

Number of Generated Files: 1.394.205 ***files***

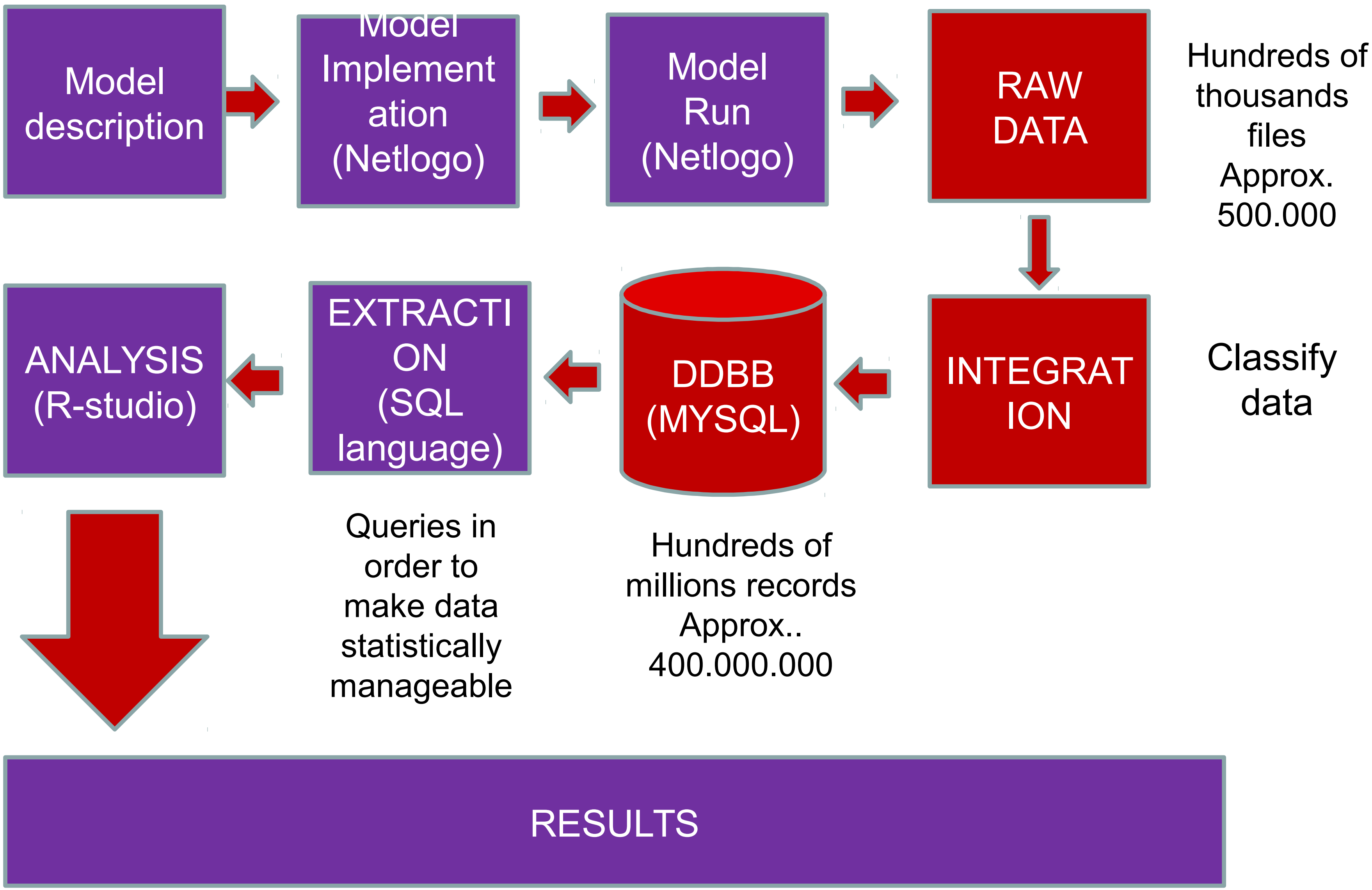
First Scenario: 10 agents at start up
- 30 runs, 700 cicles simulated at each run: 116639 files (Current State of each agent at each tick)
- 30 runs, 700 cicles simulated at each run: 116639 files (Number of líving Agents by tick)
- 30 runs, 700 cicles simulated at each run: 96123 files (Current State of each SuperAgent at each tick
- 30 runs, 700 cicles simulated at each run: 116639 files (Global paràmetres of each run)

Second Scenario: 100 agents at start up
- 30 runs, 700 cicles simulated at each run: 116639 files (Current State of each agent at each tick)
- 30 runs, 700 cicles simulated at each run: 116639 files (Number of líving Agents by tick)
- 30 runs, 700 cicles simulated at each run: 116150 files (Current State of each SuperAgent at each tick
- 30 runs, 700 cicles simulated at each run: 116639 files (Global paràmetres of each run)

Third Scenario: 200 agents at start up
- 30 runs, 700 cicles simulated at each run: 116639 files (Current State of each agent at each tick)
- 30 runs, 700 cicles simulated at each run: 116639 files (Number of líving Agents by tick)
- 30 runs, 700 cicles simulated at each run: 116633 files (Current State of each SuperAgent at each tick
- 30 runs, 700 cicles simulated at each run: 116639 files (Global paràmetres of each run)

Fourth Scenario: 400 agents at start-up
30 runs, 700 cicles simulated at each run: Number of Agent Files
- 2 runs, 700 cicles simulated at each run: 3887 files (Current State of each agent at each tick)
- 2 runs, 700 cicles simulated at each run: 3887 files (Number of líving Agents by tick)
- 2 runs, 700 cicles simulated at each run: 3887 iles (Current State of each SuperAgent at each tick
- 2 runs, 700 cicles simulated at each run: 3887 files (Global paràmetres of each run)

A data base model for Millions of records



MySQL Processing
Obtaining a DataBase for Statistical Analysis

FOR EACH RUN (IUE) **FOR EACH SELECTED TICK FROM EACH RUN**

IUE: Number of Run
TICK: Selected cicles from each run: Select:
0,
1,
50,
51,
100,
101,
200,
201,
300,
301,
400,
401,
500,
501,
698,
699.

GLOBAL PARAMETERS AT START UP
COOPERATION ALLOWED: STATE VARIABLE
INITIAL POPULATION MEAN OF RESOURCES
STAND. DEVIATION OF RESOURCES
SEASON: Even Number of Tick= HOT;
Odd Number of Tick= COLD
INITIAL TECHNOLOGY
INITIAL STORING FACTOR
DIVERSITY
AVERAGE LABOR UNITS PER AGENT
AVERAGE POSSIBILITY FOR MOVEMENT
RANDOM CHANGE RATIO –ICR

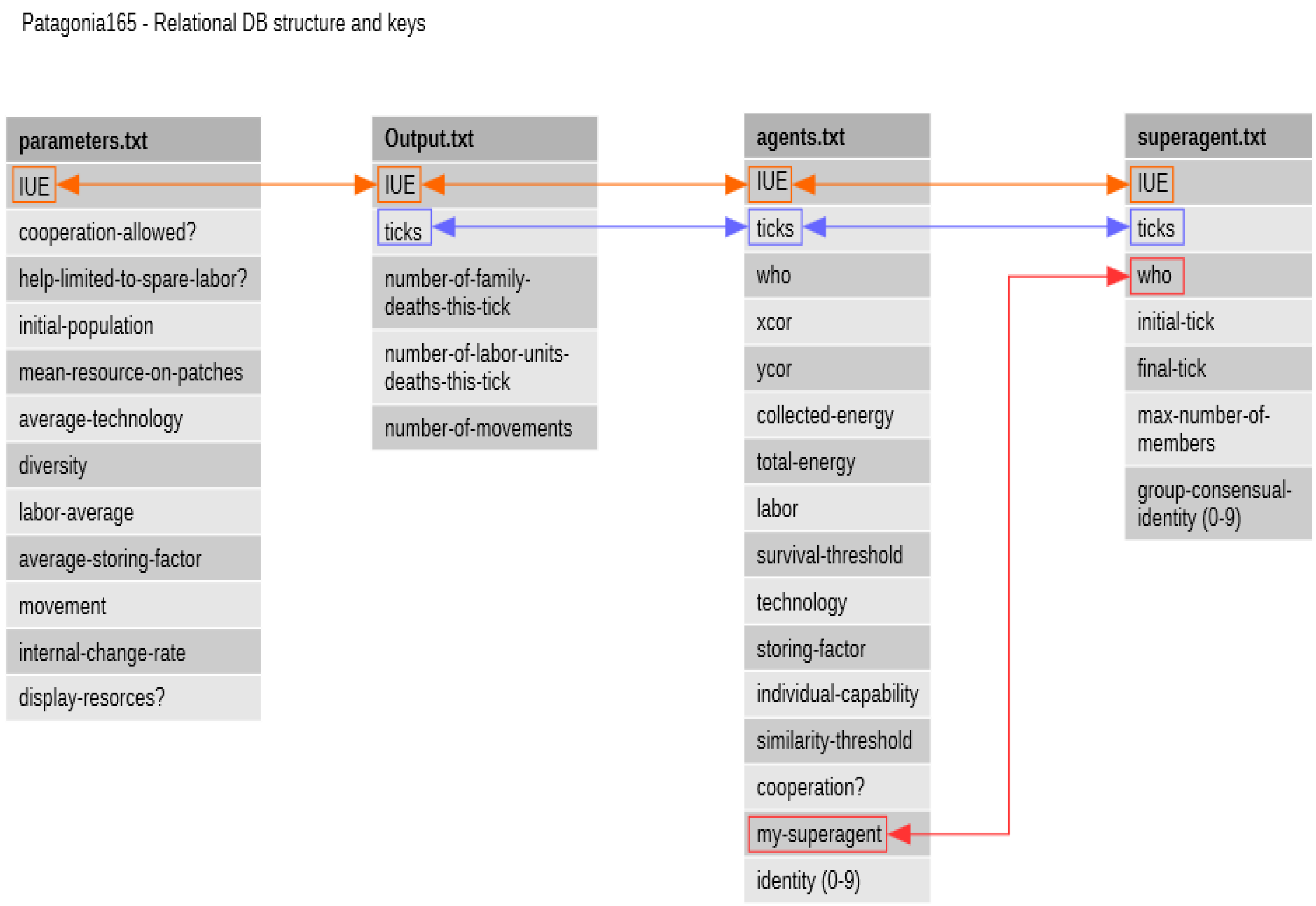
DEMOGRAPHY AND SURVIVAL
NUMBER OF LIVING AGENTS AT THE CURRENT TICK
TOTAL NUMBER OF LABOR UNITS AT THE CURRENT TICK
NUMBER OF LABOUR UNITS DEATHS THIS TICK
AVERAGE OF COLLECTED ENERGY PER AGENT AT THE CURRENT TICK

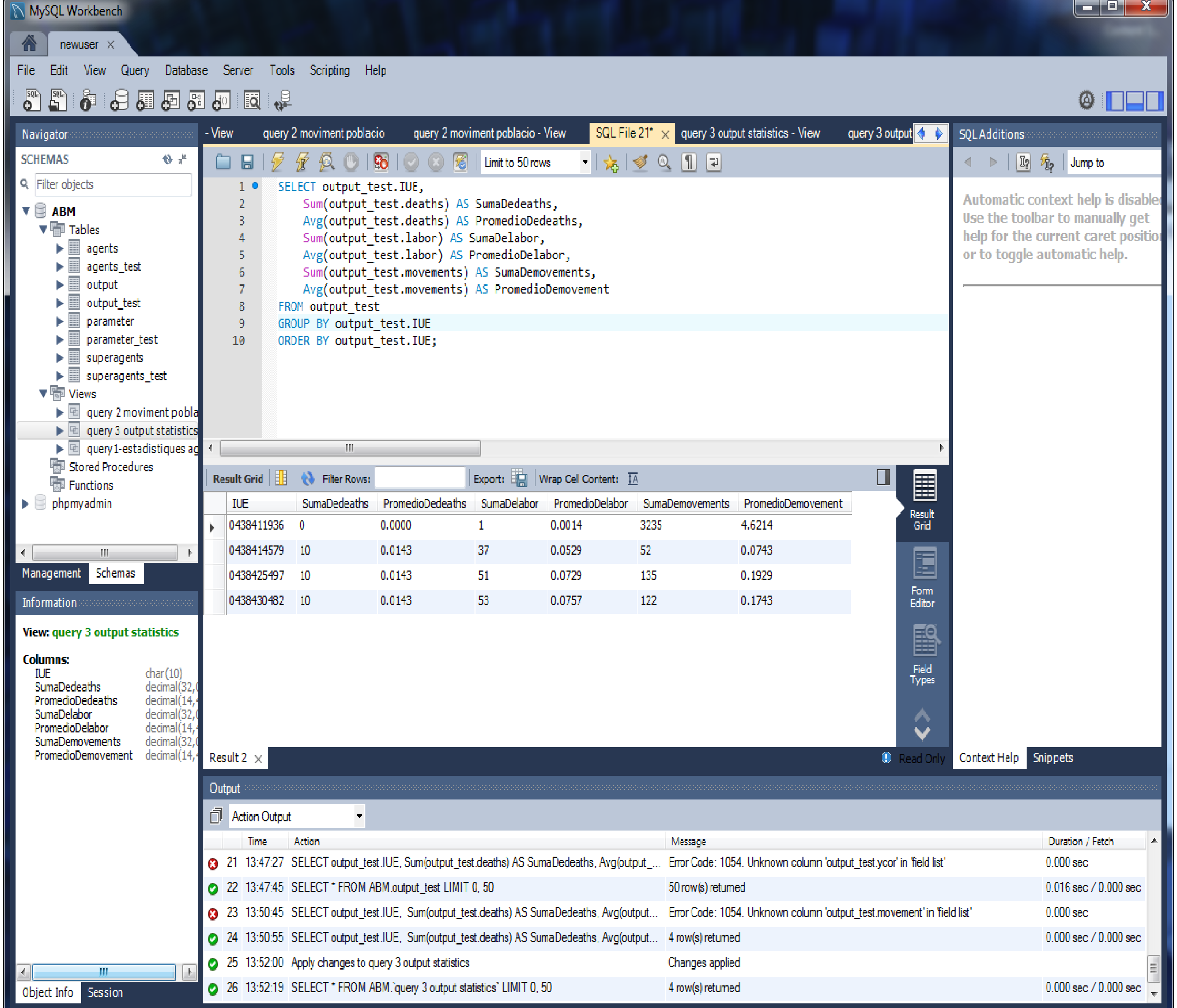
COOPERATION
CURRENT NUMBER OF COOPERATIVE AGE
CURRENT NUMBER OF LIVING SUPERAGEN
AVERAGE DURATION OF LIVING AGENTS AT CURRENT TICK
AVERAGE SIMARITY-THRESHOLD AT THE CURRENT TICK

GLOBAL MEASURES OF CULTURAL DIVERSITY
SOCIAL FRACTIONALIZATION
DEPTH OF DIFFERENCES
GENERALIZATION OF FRACTIONALIZATION
GENERALIZED RESSEMBLANCE
GENERALIZED SPATIAL AGGREGATION

SOCIAL INTERACTION
MAXIMUM VALUE OF TECHNOLOGY BY ANY AGENT AT THE CURRENT TICK
MINIMUM VALUE OF TECHNOLOGY BY ANY AGENT AT THE CURRENT TICK
MAXIMUM VALUE OF STORING FACTOR BY ANY AGENT AT THE CURRENT TICK
MINIMUM VALUE OF STORING FACTOR BY ANY AGENT AT THE CURRENT TICK

MySQL Processing
3. Obtaining a DataBase for Statistical Analysis

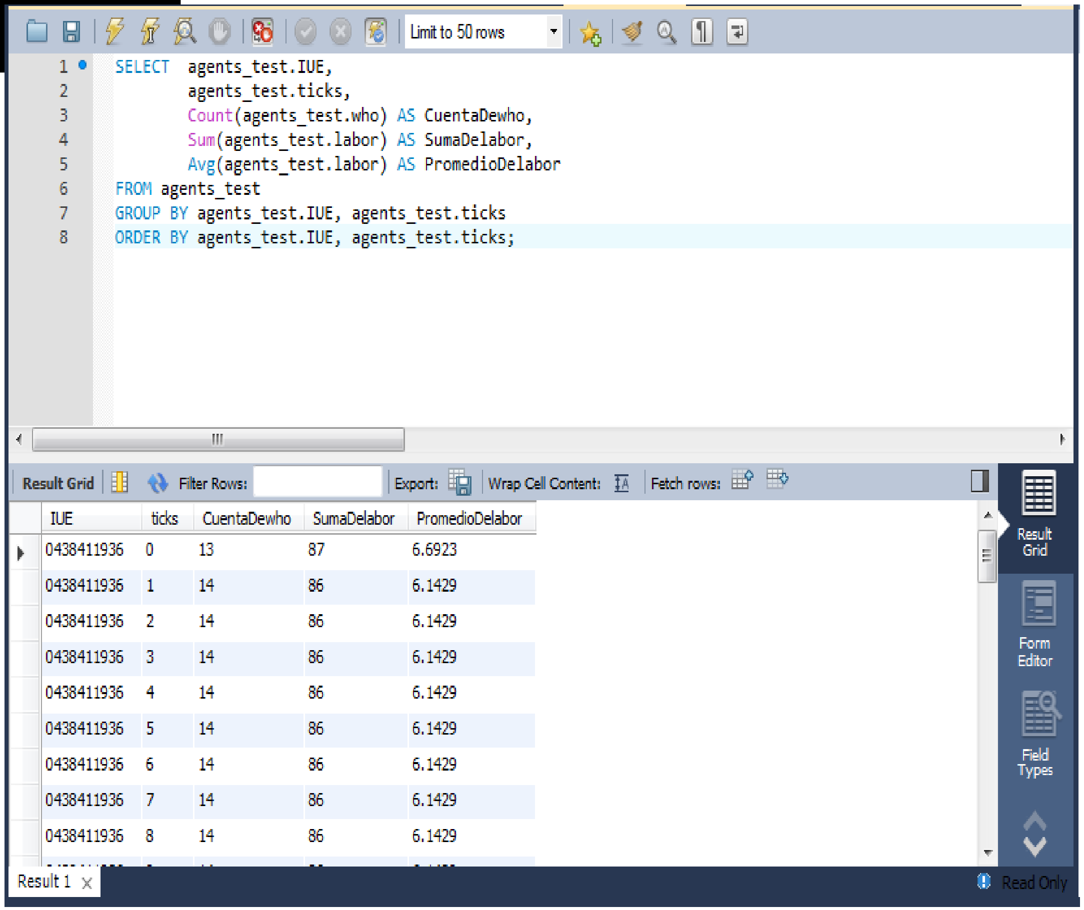



MySQL Workbench
newuser
File Edit View Query Database Server Tools Scripting Help
Navigator
SCHEMAS
Filter objects
ABM
Tables
agents
agents_test
output
output_test
parameter
parameter_test
superagents
superagents_test
Views
query 2 moviment pobla
query 3 output statistics
query1-estadistiques ag
Stored Procedures
Functions
phpmyadmin
Management
Schemas
Information
View: query 3 output statistics
Columns:
IUE char(10)
SumaDedeaths decimal(32,
PromedioDedeaths decimal(14,
SumaDelabor decimal(32,
PromedioDelabor decimal(14,
SumaDemovements decimal(32,
PromedioDemovement decimal(14,
Object Info
Session
- View
query 2 moviment poblacio
query 2 moviment poblacio - View
SQL File 21*
query 3 output statistics - View
query 3 output
Limit to 50 rows
SELECT output_test.IUE,
Sum(output_test.deaths) AS SumaDedeaths,
Avg(output_test.deaths) AS PromedioDedeaths,
Sum(output_test.labor) AS SumaDelabor,
Avg(output_test.labor) AS PromedioDelabor,
Sum(output_test.movements) AS SumaDemovements,
Avg(output_test.movements) AS PromedioDemovement
FROM output_test
GROUP BY output_test.IUE
ORDER BY output_test.IUE;
Result Grid
Filter Rows:
Export:
Wrap Cell Content:
IUE SumaDedeaths PromedioDedeaths SumaDelabor PromedioDelabor SumaDemovements PromedioDemovement
0438411936 0 0.0000 1 0.0014 3235 4.6214
0438414579 10 0.0143 37 0.0529 52 0.0743
0438425497 10 0.0143 51 0.0729 135 0.1929
0438430482 10 0.0143 53 0.0757 122 0.1743
Result Grid
Form Editor
Field Types
Result 2
Read Only
SQL Additions
Jump to
Automatic context help is disable
Use the toolbar to manually get
help for the current caret positio
or to toggle automatic help.
Context Help
Snippets
Output
Action Output
Time Action Message Duration / Fetch
21 13:47:27 SELECT output_test.IUE, Sum(output_test.deaths) AS SumaDedeaths, Avg(output_... Error Code: 1054. Unknown column 'output_test.ycor' in 'field list' 0.000 sec
22 13:47:45 SELECT * FROM ABM.output_test LIMIT 0, 50 50 row(s) returned 0.016 sec / 0.000 sec
23 13:50:45 SELECT output_test.IUE, Sum(output_test.deaths) AS SumaDedeaths, Avg(output... Error Code: 1054. Unknown column 'output_test.movement' in 'field list' 0.000 sec
24 13:50:55 SELECT output_test.IUE, Sum(output_test.deaths) AS SumaDedeaths, Avg(output... 4 row(s) returned 0.000 sec / 0.000 sec
25 13:52:00 Apply changes to query 3 output statistics Changes applied
26 13:52:19 SELECT * FROM ABM.`query 3 output statistics` LIMIT 0, 50 4 row(s) returned 0.000 sec / 0.000 sec

MySQL Processing
3. Obtaining a DataBase for Statistical Analysis

FOR EACH SELECTED TICK FROM EACH RUN

SQL QUERIES



```sql
SELECT  agents_test.IUE,
        agents_test.ticks,
        Count(agents_test.who) AS CuentaDewho,
        Sum(agents_test.labor) AS SumaDelabor,
        Avg(agents_test.labor) AS PromedioDelabor
FROM agents_test
GROUP BY agents_test.IUE, agents_test.ticks
ORDER BY agents_test.IUE, agents_test.ticks;
```

IUE	ticks	CuentaDewho	SumaDelabor	PromedioDelabor
0438411936	0	13	87	6.6923
0438411936	1	14	86	6.1429
0438411936	2	14	86	6.1429
0438411936	3	14	86	6.1429
0438411936	4	14	86	6.1429
0438411936	5	14	86	6.1429
0438411936	6	14	86	6.1429
0438411936	7	14	86	6.1429
0438411936	8	14	86	6.1429

MySQL Processing
3. Obtaining a DataBase for Statistical Analysis

FOR EACH SELECTED TICK FROM EACH RUN

SQL QUERIES

COOPERATION
CURRENT NUMBER OF COOPERATIVE AGENTS
CURRENT NUMBER OF LIVING SUPERAGENTS
AVERAGE DURATION OF LIVING AGENTS AT THE CURRENT TICK
AVERAGE SIMARITY-THRESHOLD AT THE CURRENT TICK

```
SELECT DISTINCTROW
superagents_test.iue,
superagents_test.ticks,
superagents_test.who
      FROM superagents_test
      GROUP BY superagents_test.iue,
superagents_test.ticks,
superagents_test.who
      ORDER BY superagents_test.iue,
superagents_test.ticks;
```

MySQL Processing
3. Obtaining a DataBase for Statistical Analysis

FOR EACH SELECTED TICK FROM EACH RUN SQL QUERIES

COOPERATION

CURRENT NUMBER OF COOPERATIVE AGENTS

CURRENT NUMBER OF LIVING SUPERAGENTS

AVERAGE DURATION OF LIVING AGENTS AT THE CURRENT TICK

AVERAGE SIMARITY-THRESHOLD AT THE CURRENT TICK

1	IUE	ticks	who	initial-tick	final-tick	max-number-of-members
2	100006656	1	10	1	0	10
3	100006656	2	10	1	2	10
4	100006656	3	11	3	0	10
5	100006656	4	11	3	4	10
6	100006656	59	13	59	0	
7	100006656	60	13	59	60	
8	100006656	87	15	87	0	
9	100006656	88	15	87	88	12
10	100006656	131	19	131	0	15
11	100006656	132	19	131	132	15
12	100006656	133	20	133	0	15
13	100006656	134	20	133	134	15
14	100006656	137	21	137	0	15
15	100006656	138	21	137	138	15
16	100006656	139	22	139	0	15
17	100006656	140	22	139	140	15
18	100006656	159	25	159	0	15
19	100006656	160	25	159	160	15
20	100006656	161	26	161	0	16
21	100006656	162	26	161	162	16
22	100006656	163	27	163	0	15
23	100006656	164	27	163	164	15
24	100006656	165	28	165	0	15
25	100006656	166	28	165	0	15
26	100006656	167	28	165	0	
27	100006656	168	28	165	168	
28	100006656	185	32	185	0	
29	100006656	186	32	185	186	18
30	100006656	189	33	189	0	16
31	100006656	190	33	189	190	16

Superagent 13 is created at tick 59 and it dies at tick 60

Superagente 28 is created at tick 165 and it dies at tick 168

MySQL Processing
3. Obtaining a DataBase for Statistical Analysis

FOR EACH SELECTED TICK FROM EACH RUN   SQL QUERIES

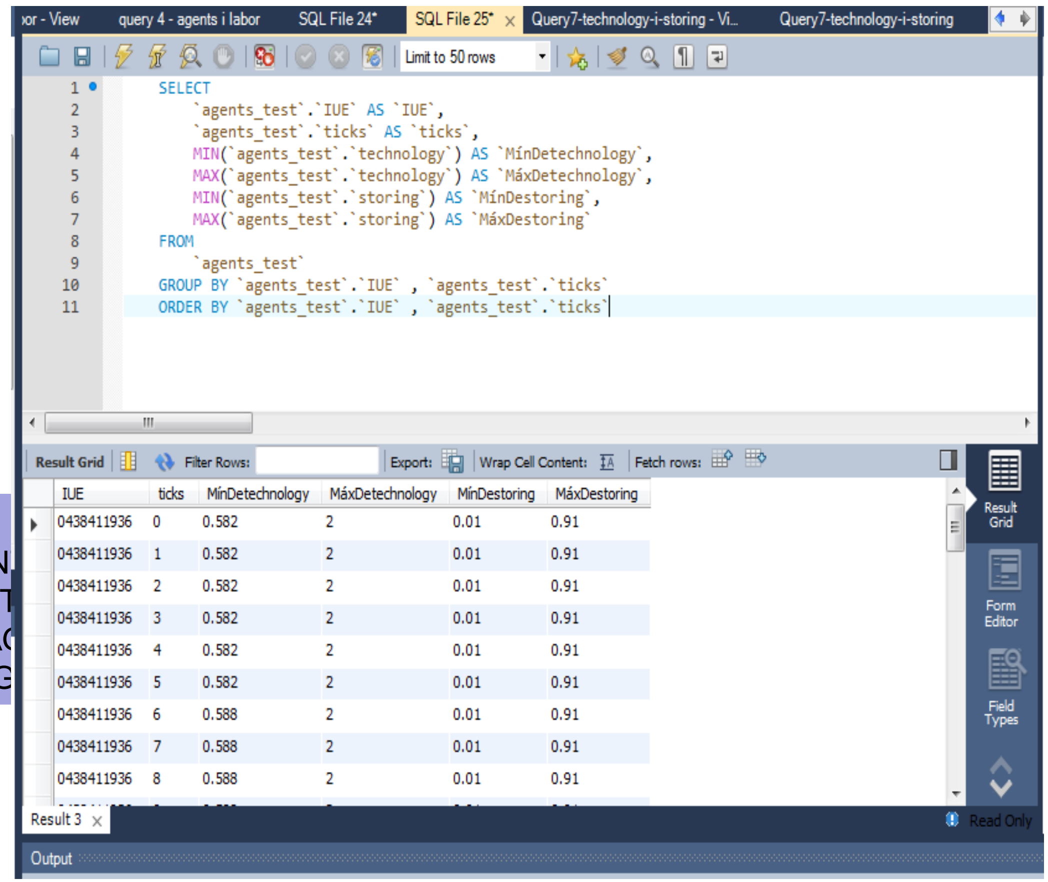
COOPERATION
CURRENT NUMBER OF COOPERATIVE AGENTS
CURRENT NUMBER OF LIVING SUPERAGENTS
AVERAGE DURATION OF LIVING AGENTS AT THE CURRENT TICK
AVERAGE SIMARITY-THRESHOLD AT THE CURRENT TICK

```
CREATE
    ALGORITHM = UNDEFINED
    DEFINER = `newuser`@`%`
    SQL SECURITY DEFINER
VIEW `query 2 moviment poblacio` AS
    SELECT
        `agents_test`.`IUE` AS `IUE`,
        `agents_test`.`ticks` AS `ticks`,
        MIN(`agents_test`.`xcor`) AS `xmin`,
        MAX(`agents_test`.`xcor`) AS `xmax`,
        MIN(`agents_test`.`ycor`) AS `ymin`,
        MAX(`agents_test`.`ycor`) AS `ymax`
    FROM
        `agents_test`
    GROUP BY `agents_test`.`IUE` ,
`agents_test`.`ticks`
    ORDER BY `agents_test`.`IUE` ,
`agents_test`.`ticks`
```

MySQL Processing
3. Obtaining a DataBase for Statistical Analysis

FOR EACH SELECTED TICK FROM EACH RUN

SQL QUERIES



SOCIAL INTERACTION

MAXIMUM VALUE OF TECHNOLOGY BY ANY AGEN

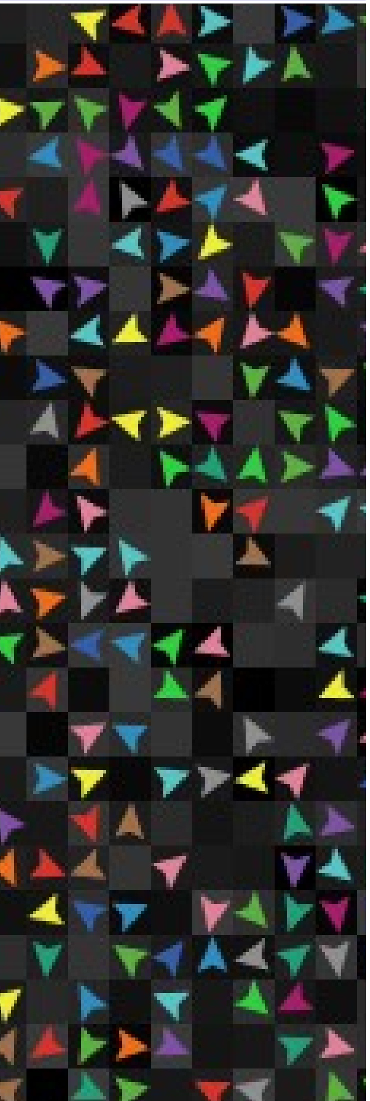
MINIMUM VALUE OF TECHNOLOGY BY ANY AGENT

MAXIMUM VALUE OF STORING FACTOR BY ANY AG

MINIMUM VALUE OF STORING FACTOR BY ANY AG

MySQL Processing

1. File Aggregation



Four files

Each record
is a description of each agent
at each tick (Cycle) for each run.

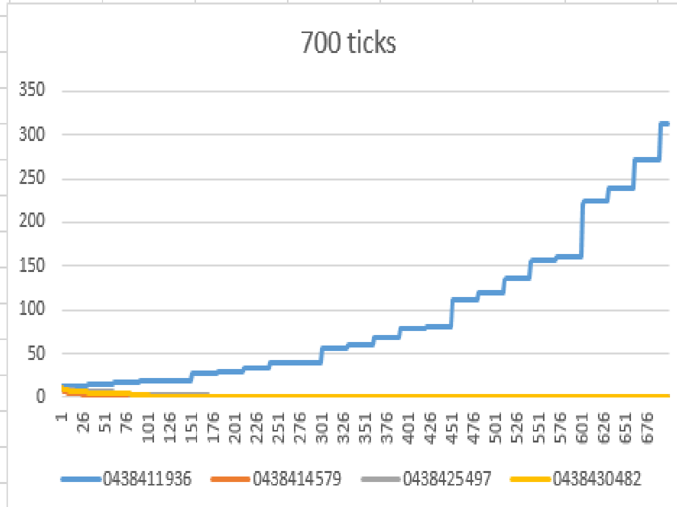
Initial population =10
3 million RECORDS

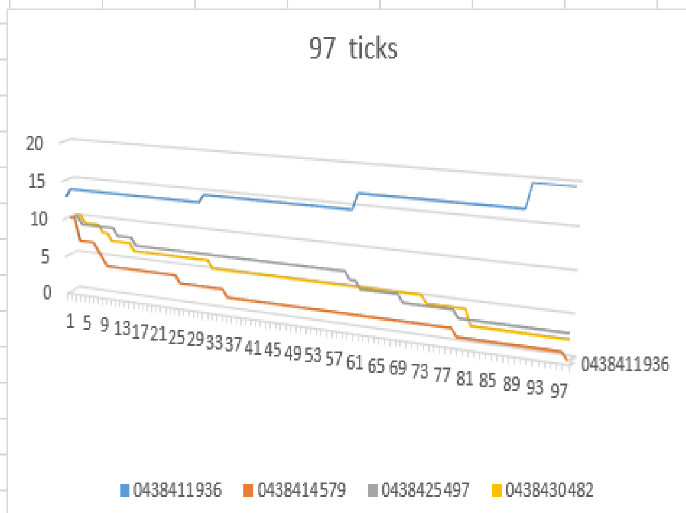
Initial population =100
More than 3 million RECOR

Initial population =200
More than 5 million RECOR

Initial population =400
700 records

A	B	C	D	E
	IUE	IUE	IUE	IUE
	0438411936	0438414579	0438425497	0438430482
ticks	who	who	who	who
0	13	10	10	10
1	14	10	10	10
2	14	7	9	9
3	14	7	9	9
4	14	7	9	9
5	14	7	9	9
6	14	6	9	8
7	14	5	9	8
8	14	4	9	7
9	14	4	9	7
10	14	4	8	7
11	14	4	8	7
12	14	4	8	7
13	14	4	8	6
14	14	4	7	6
15	14	4	7	6
16	14	4	7	6
17	14	4	7	6
18	14	4	7	6
19	14	4	7	6
20	14	4	7	6
21	14	4	7	6
22	14	4	7	6
23	14	4	7	6
24	14	3	7	6
25	14	3	7	6
26	14	3	7	6
27	14	3	7	6
28	14	3	7	6
29	14	3	7	6
30	15	3	7	5

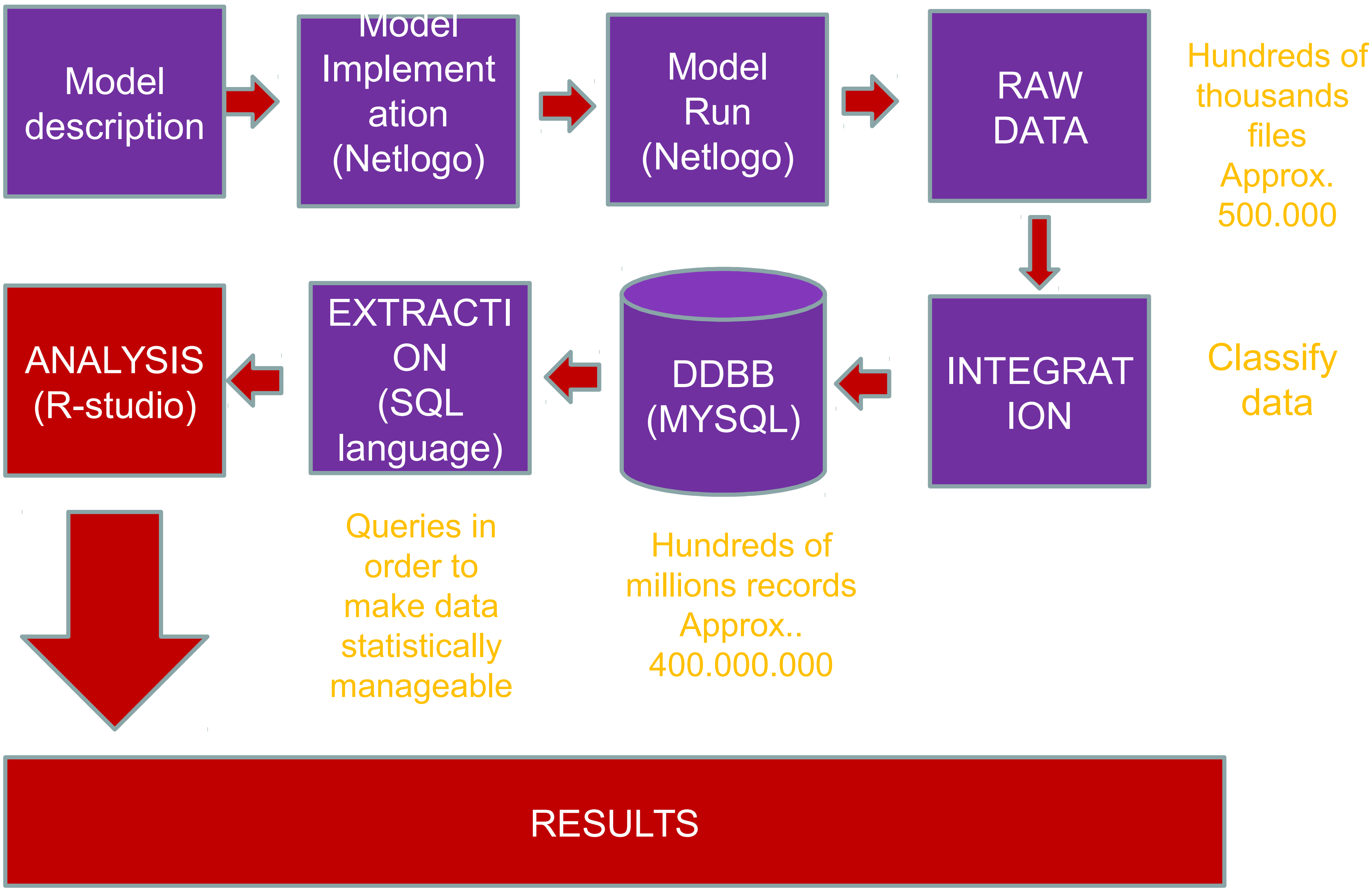




We have selected c
Cycle (warm seasor
one cycle (cold sea
every 100 cycles.

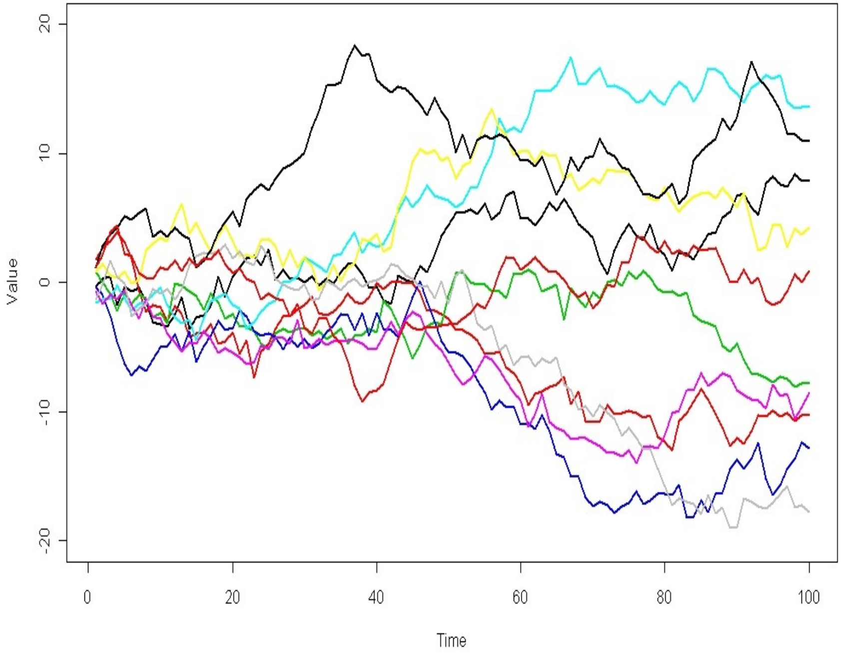
Resulting file has
300000 records.
For each N= 10,
N= 100,
N= 200,
N= 400

A data base model for Millions of records



Exploring the Parametric Space

The sources of Stochasticity



Before answering why each run gives
Different results, we have to measure
the global stocasticity of the system:, and to
Ask ourselves about the consequences of:

Agents find other agents
just by chance.

Individual agents have the the
possibility of refuse cooperation
without “rational” reasons
for doing it.

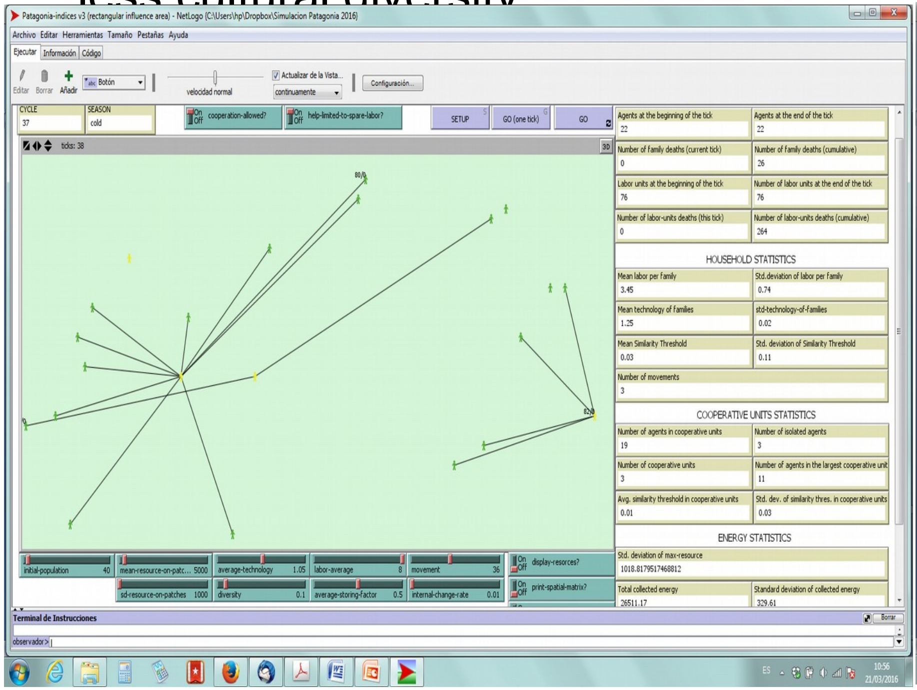
Agests “evolve” also for particular
reasons and not only as a
consequence of cooperation.

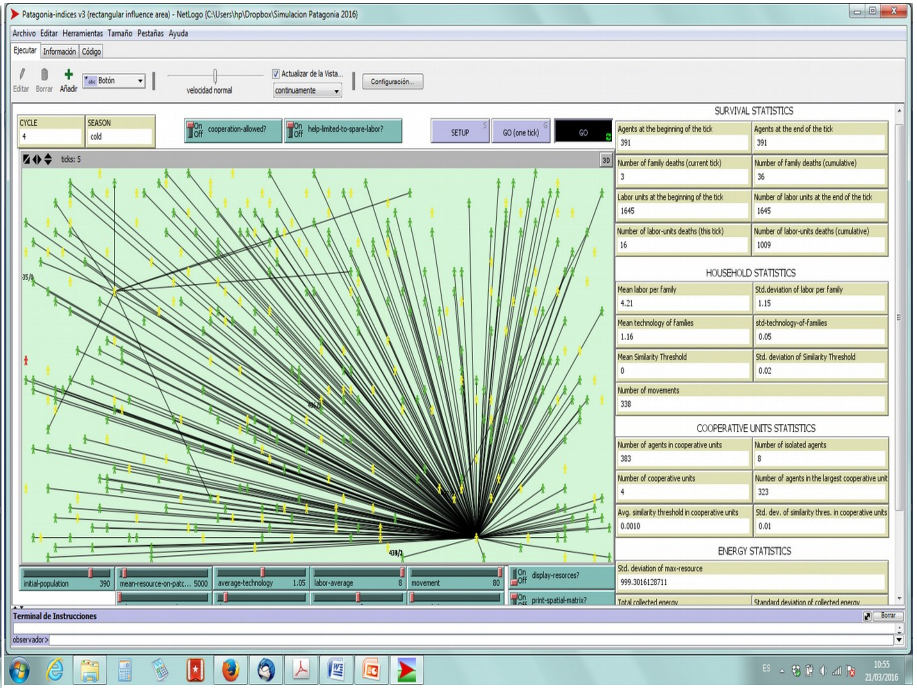
Exploring the Parametric Space

The Effects of Population size at start-up

Expected Result: the higher the population at start-up, the “easier” to build cooperation networks, the more cooperation, and the less cultural diversity

Nevertheless, the higher the population at he population will grow more, and control will become more relevant.





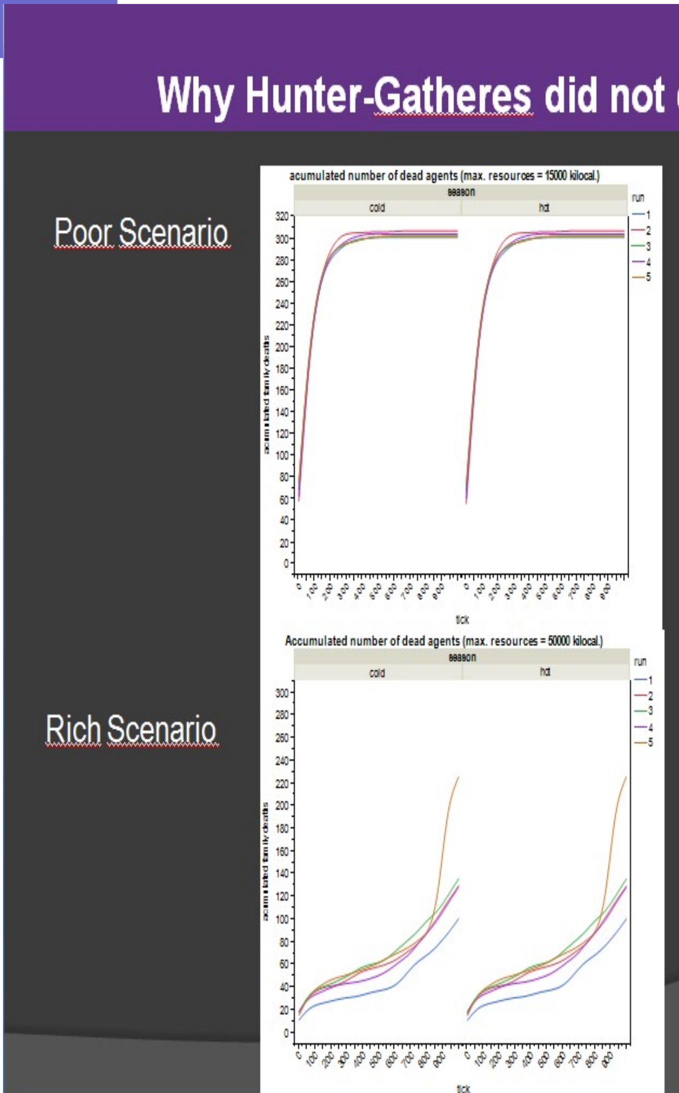
Exploring the Parametric Space

The Effects of Resource Availability

The Rich World / Poor World Scenarios

Expected Results: The poorer the world, the higher the cooperation benefits, and the more stable will be cooperation networks

Nevertheless, the poorer the world, the higher the Number of deaths, and the less population density, what is a handicap for complex cooperation networks



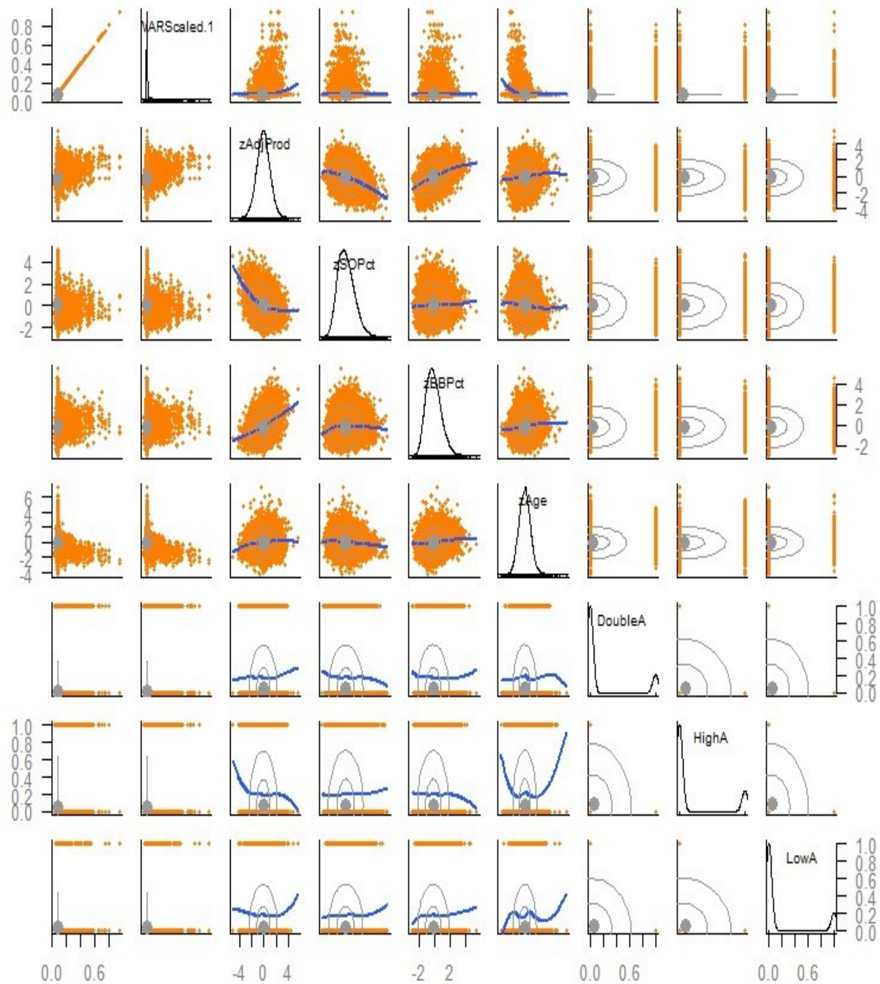
Exploring the Parametric Space

The advantages of cooperation in mobile hunter-gatherers

The similarity-threshold take values between 0 and 1, and came to represent how similar should be an agent to receive some help. It simulates the “rationality” in the decision whether to cooperate.

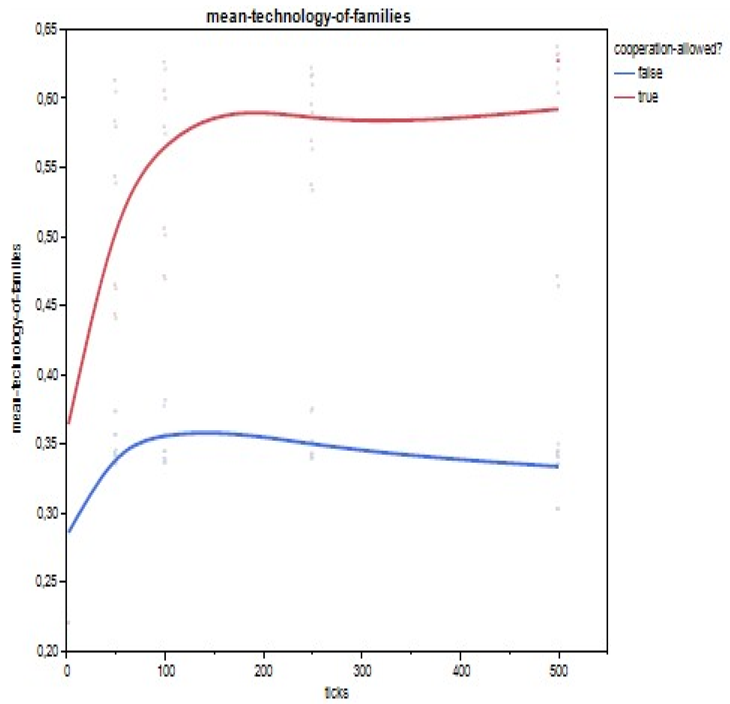
My similarity-threshold depends on many factors (number of labors, level of resources in my patch, difficulty to get them ...) but, in short, is proportional to how difficult it will be for me to reach my threshold of survival in the current tick.

There are two extreme cases: if the agent is going to achieve survival, my similarity-threshold is 0 (always help), and if the agent believes its’s not going to reach (need to ask for help) my similarity threshold is 1.



Exploring the Parametric Space

The advantages of cooperation in mobile hunter-gatherers



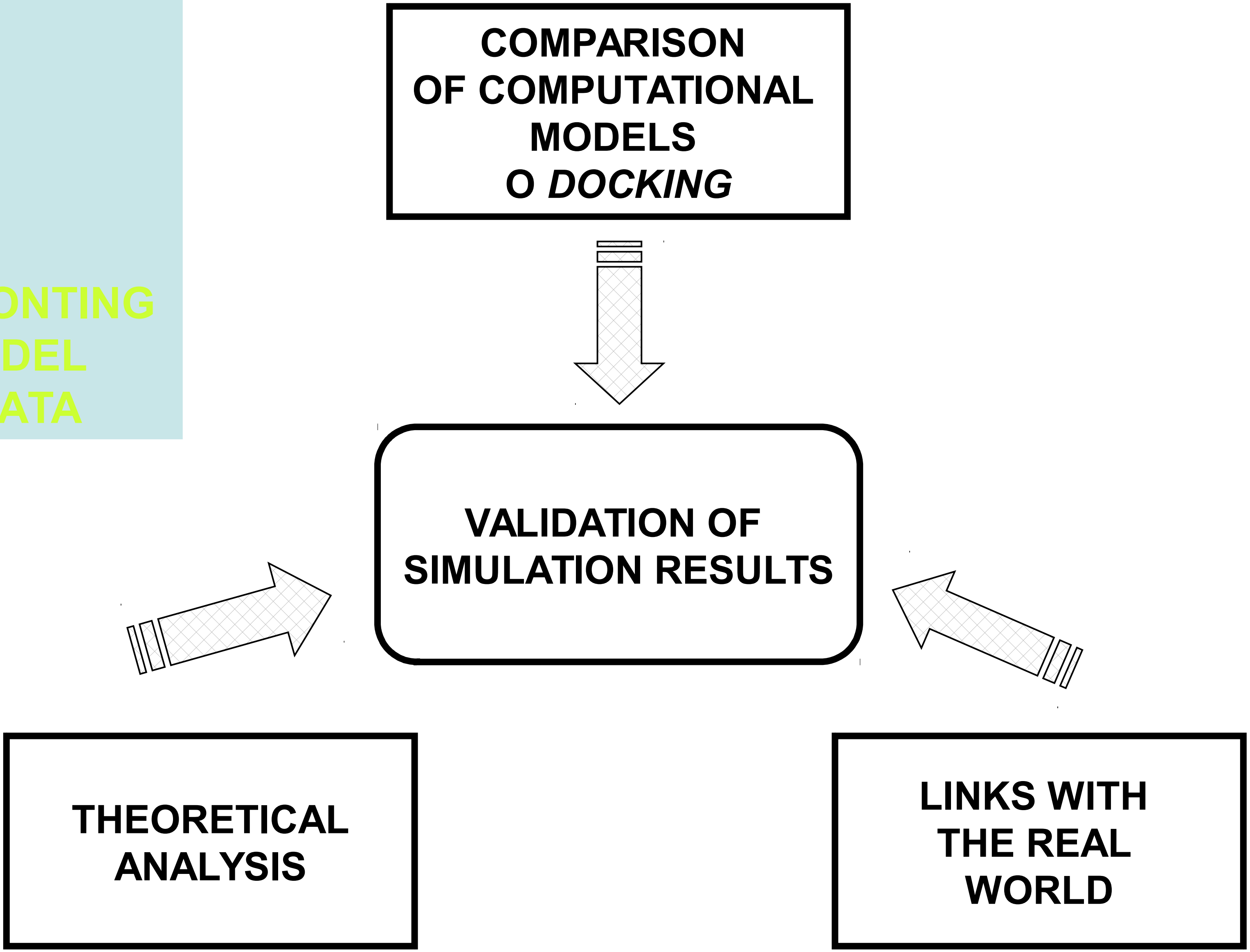
In the cooperation scenario, average-technology quickly evolves to higher values. The difference of means is statistically relevant. In the non-cooperative scenario, agents are also very different in their technological efficiency, while cooperation generates scenarios of more homogenous diffusion

The decisive question in any simulation is what evidence one has to judge the simulation to be true.

"You are completely free to carry out whatever research you want, so long as you come to these conclusions."

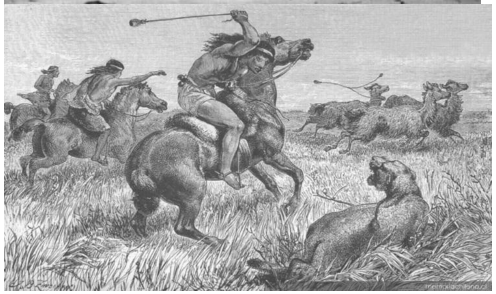
Sensitivy Analysis is not Validation: We need comparing simulated results with empirical data

CONFRONTING THE MODEL WITH DATA



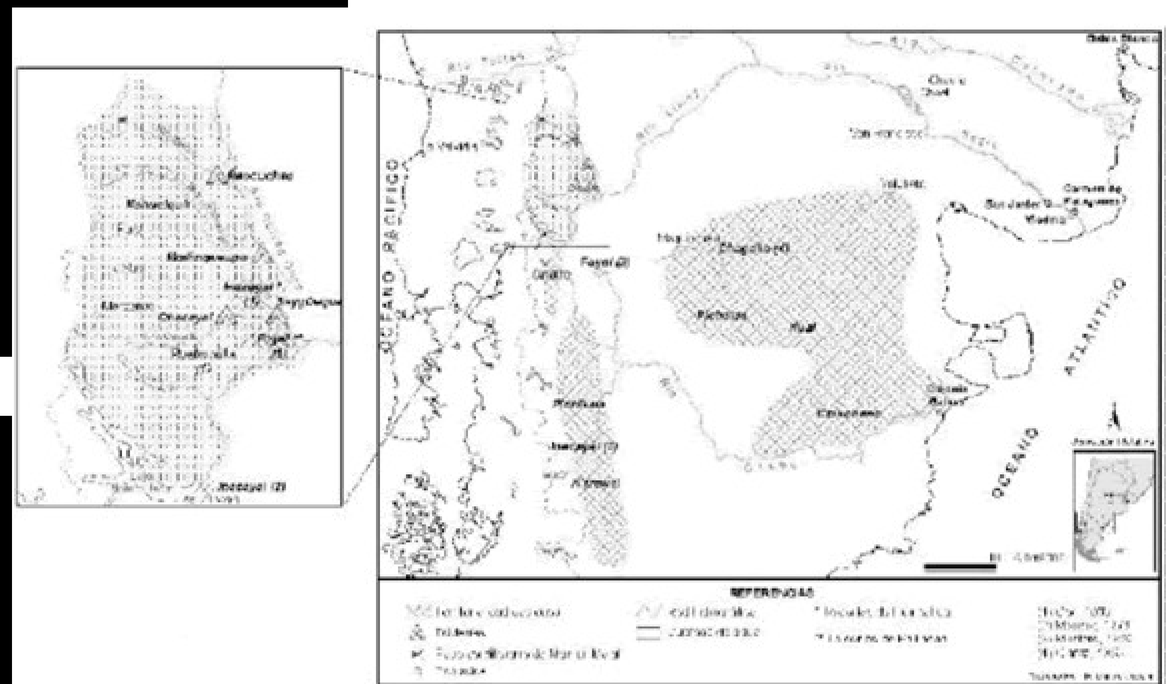
CALIBRATING THE GLOBAL THEORETICAL MODEL WITH PARTICULAR ETHNOHISTORICAL INFORMATION

Number of Families	[40]
Size of Neighborhood Area	[5]
Initial Area of Settlement	[50]
Intolerance Level	[0.2]
Num. of Cultural Dimensions	[10]
Num. of Cultural Features	[10]
Probability of cultural diffusion	[0.7]
Probability of cultural change	[0.5]
Cooperation Advantages	[4]
Subsistence	[0.2]
Energy Depretiation	[1.7]
Life Expectancy	[70]



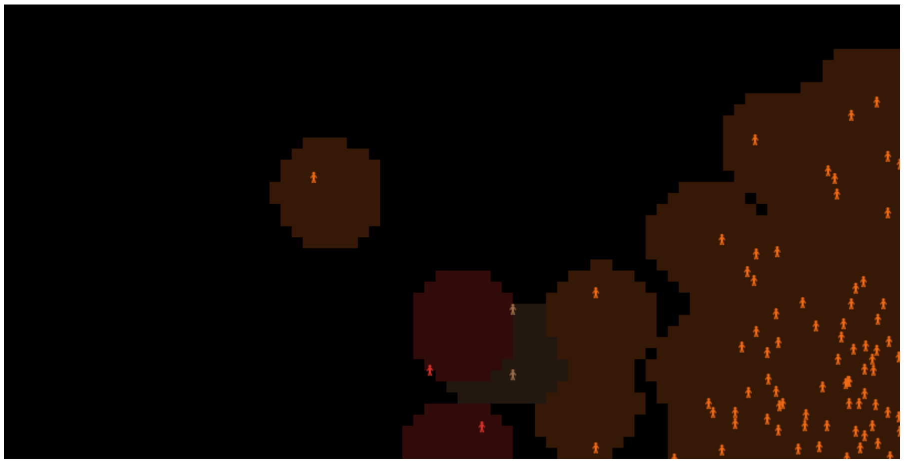
COMPARING SIMULATED RESULTS WITH ETHNONYMS

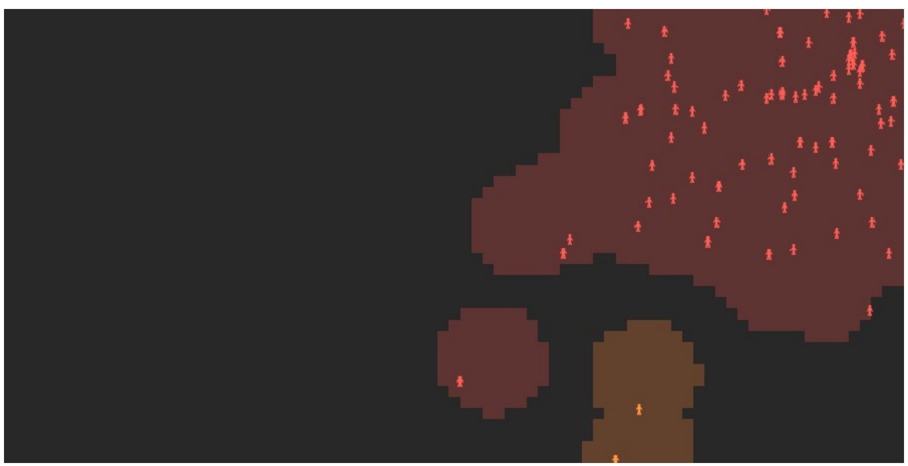
(INDIGENOUS POPULATION SELF-IDENTITY)



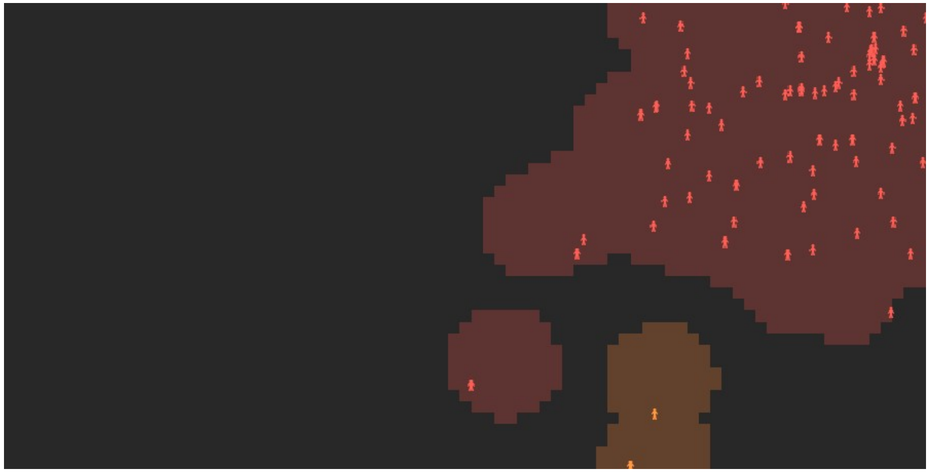
COMPARING SIMULATED RESULTS WITH ETHNONYMS

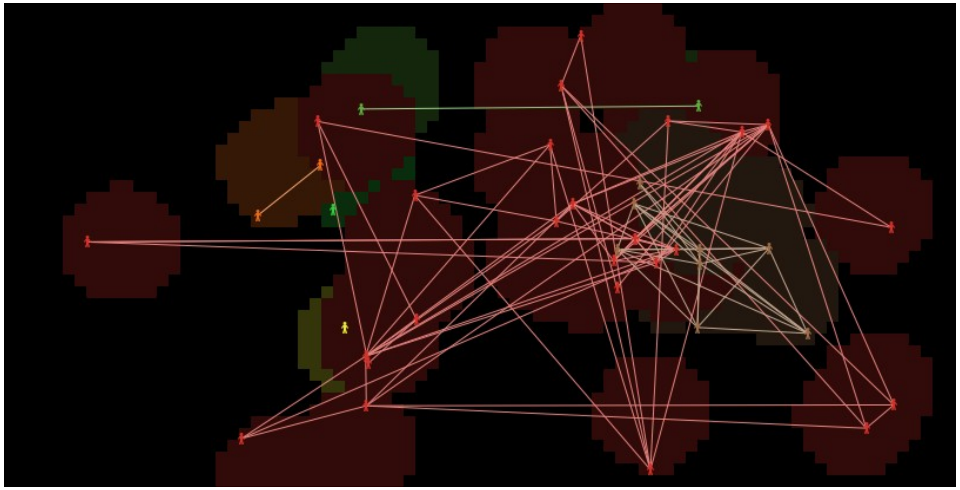
(IMPOSED ETHNICITIES)

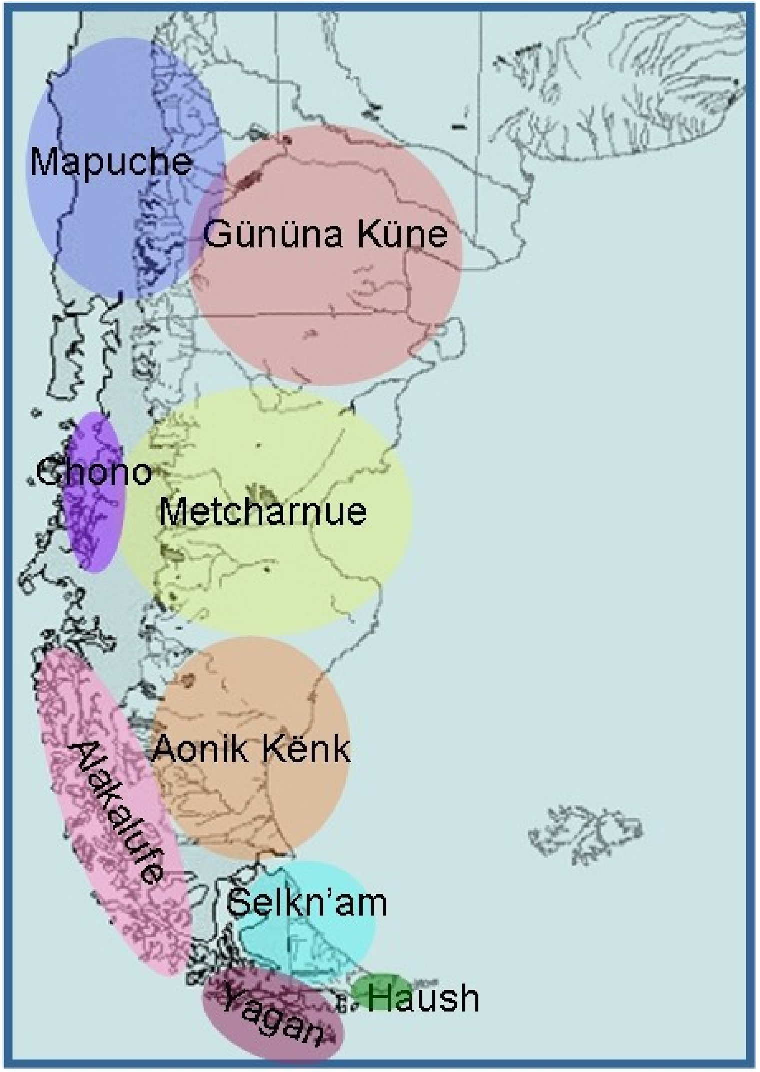




COMPARING SIMULATED RESULTS WITH LINGUISTIC DISTANCES

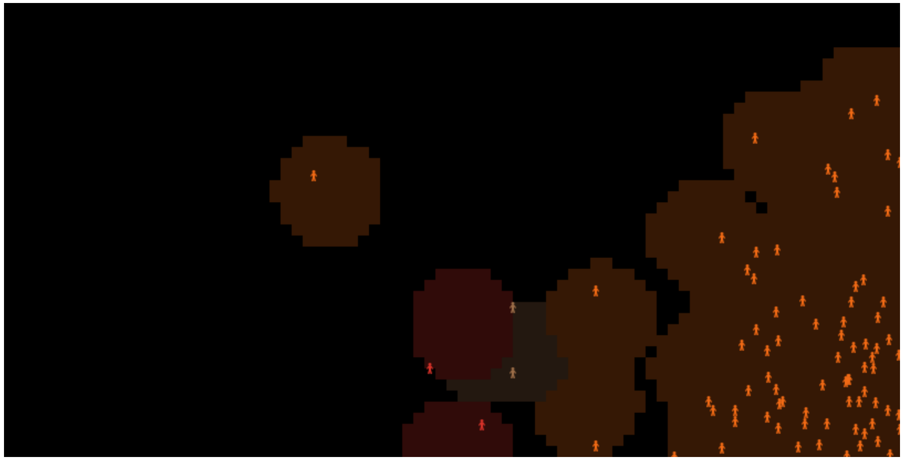


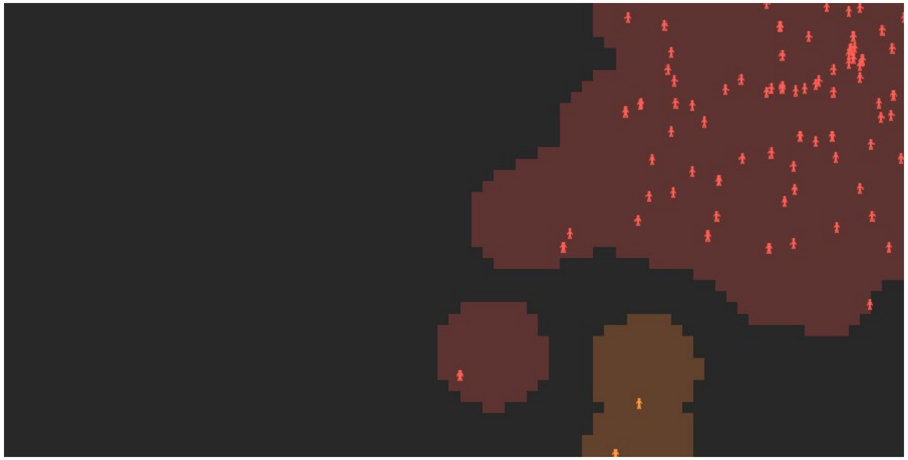


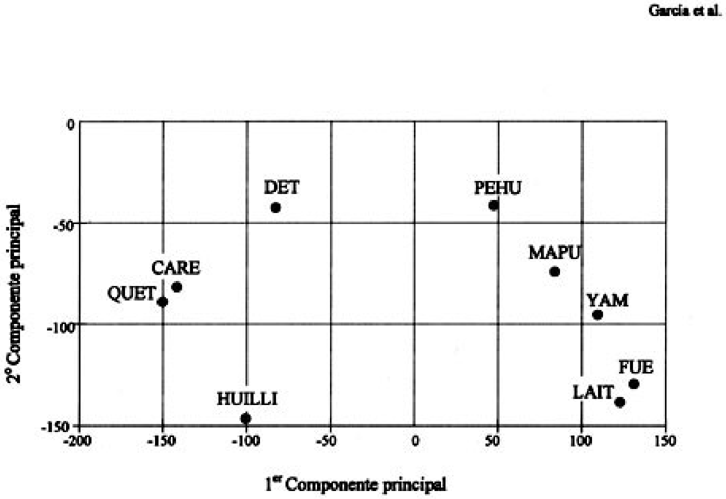


COMPARING SIMULATED RESULTS WITH ARCHAEOLOGICAL DATA

1. Genetic Distances between populations

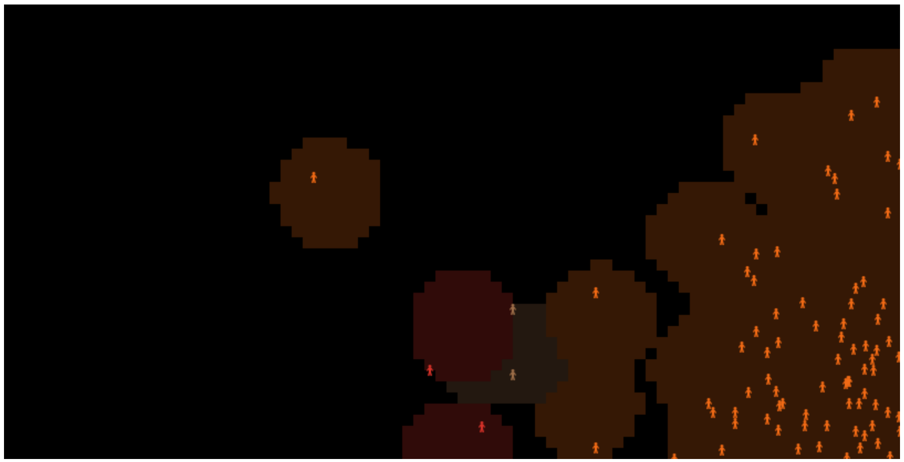


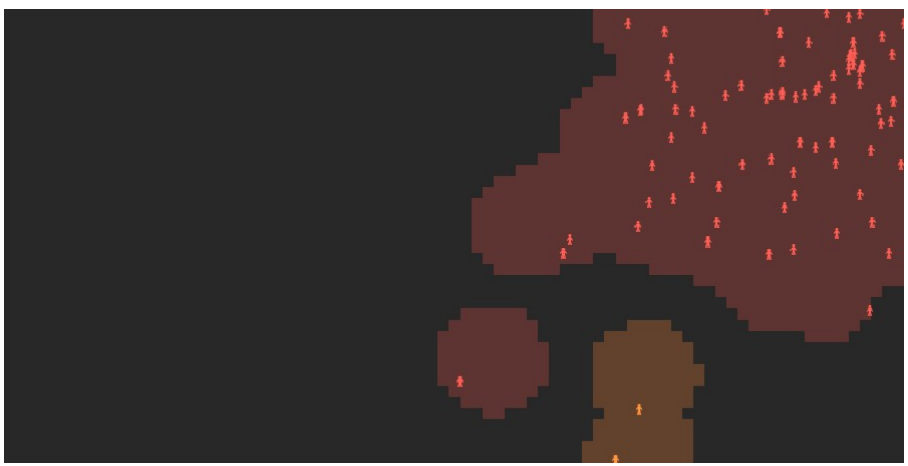


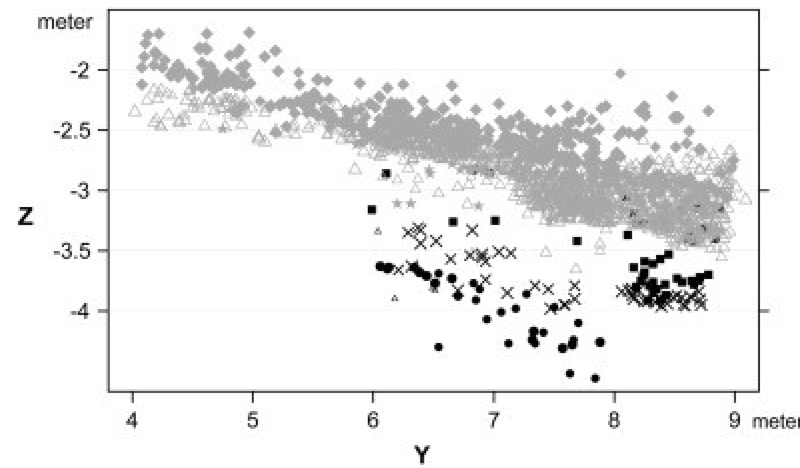


COMPARING SIMULATED RESULTS WITH ARCHAEOLOGICAL DATA

2. Archaeological Similarity between lithic tools

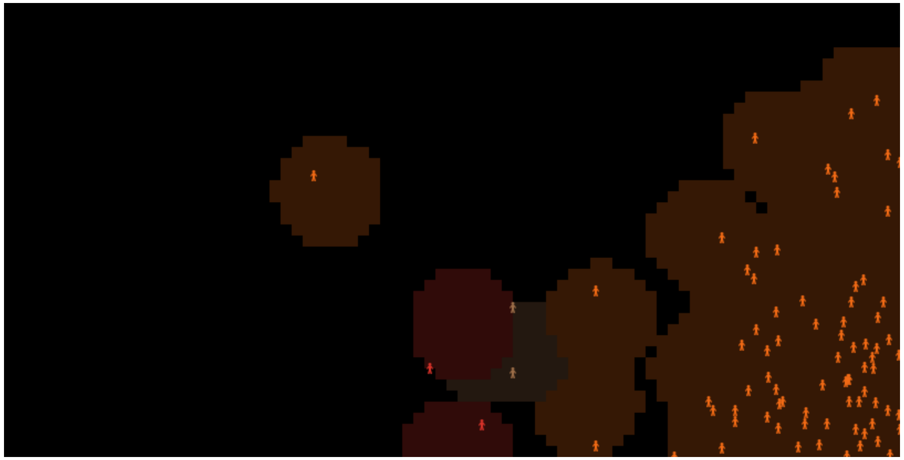


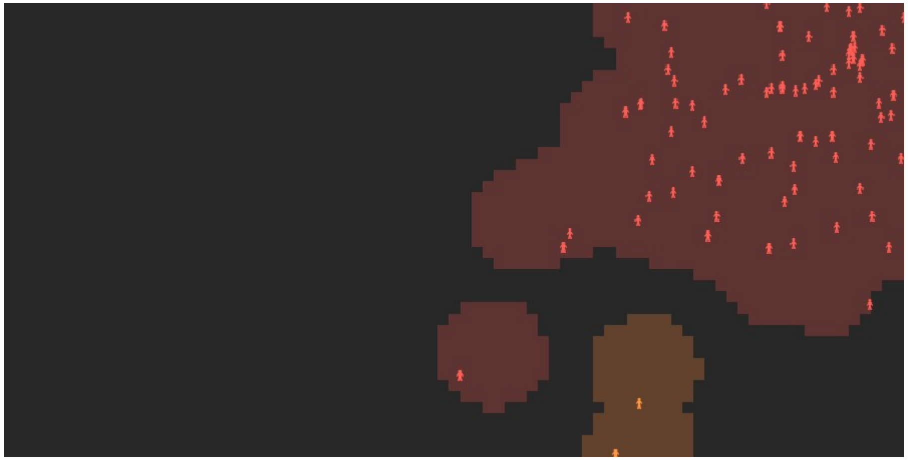




COMPARING SIMULATED RESULTS WITH ARCHAEOLOGICAL DATA

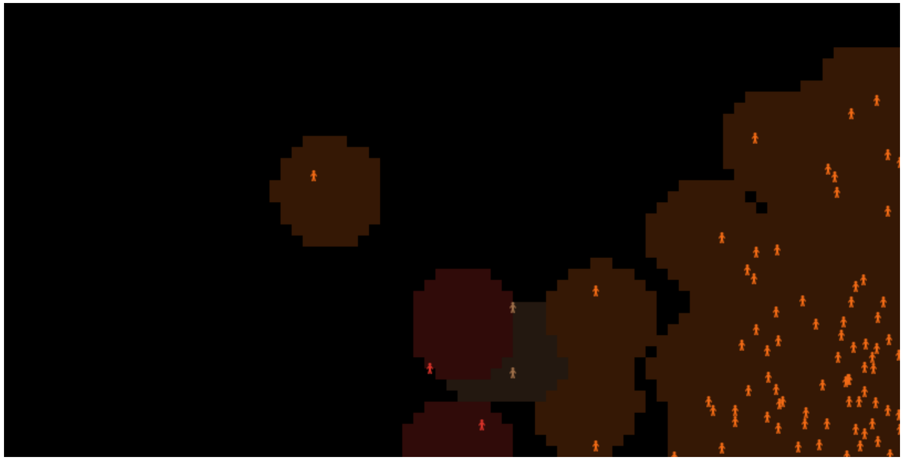
3. Archaeological Similarity between Rock Art sites

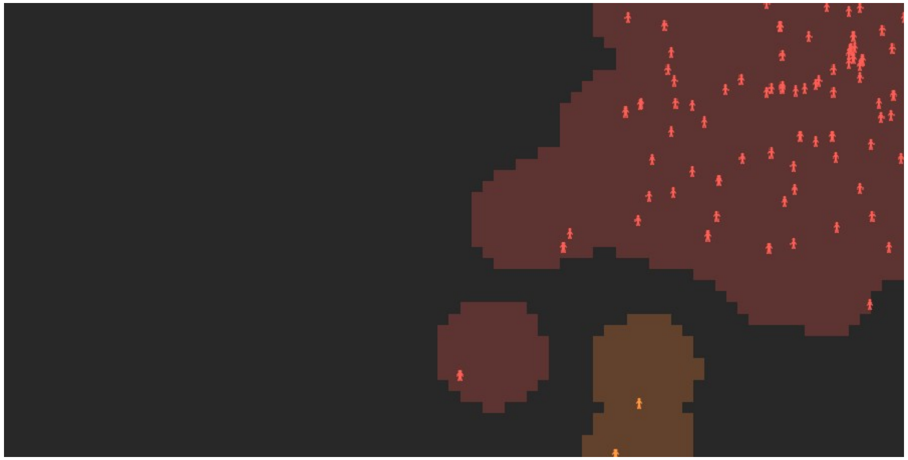


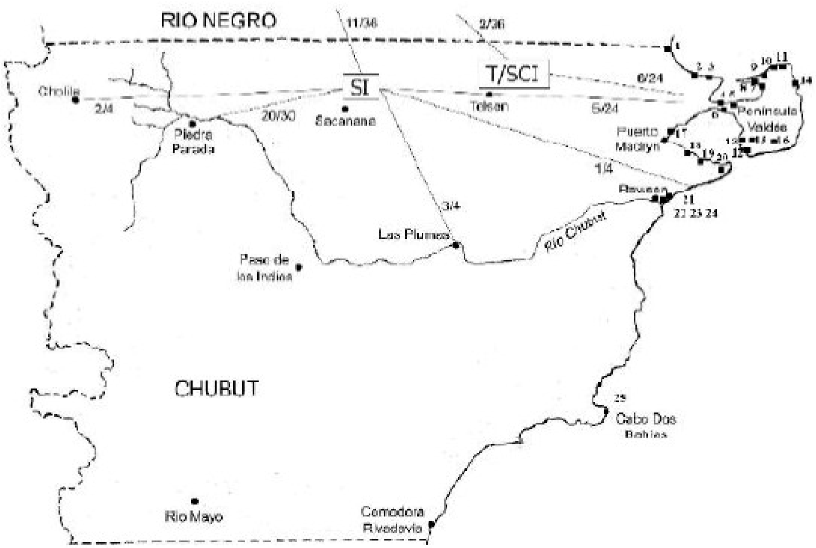


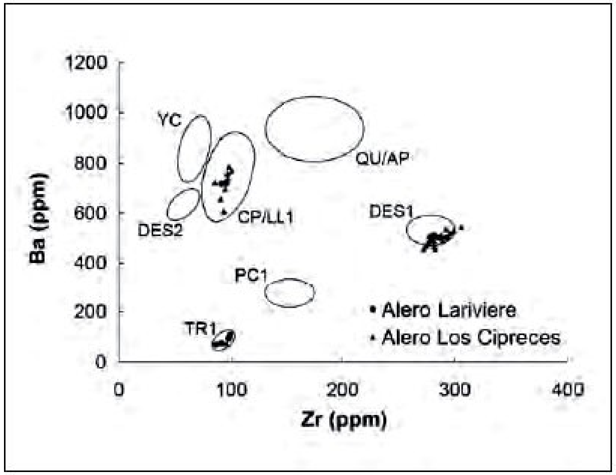
COMPARING SIMULATED RESULTS WITH ARCHAEOLOGICAL DATA

3. Prehistoric Exchange Networks: the source of raw materials









Patagonia Simple Past

Limitations and Enhancement

- **Scale of Analysis: Population dynamics**
- **Scale of Analysis: Temporal units**
- **Input variables: “Cultural” Dimensions. Measuring “Identity”**
- **Output variables: Number of Culturally Similar Groups.**
  How to measure cultural similarity. Index of Ethnic fragmentation. Degree of Social Inertia between states

5) **PROBLEMS WITH AGENT RATIONALITY:** optimal choice, bounded rationality or bayesian probability.

6) **ENHANCING THE MODEL, IMPLEMENTING NEW MECHANISMS:** Other mechanisms of cooperation restriction

a. **Landscape impact on mobility:**
   i. Atraction forces: rich resources
   ii. Repulsion forces: poor resources (negative). Topographic barriers are areas with negative resources

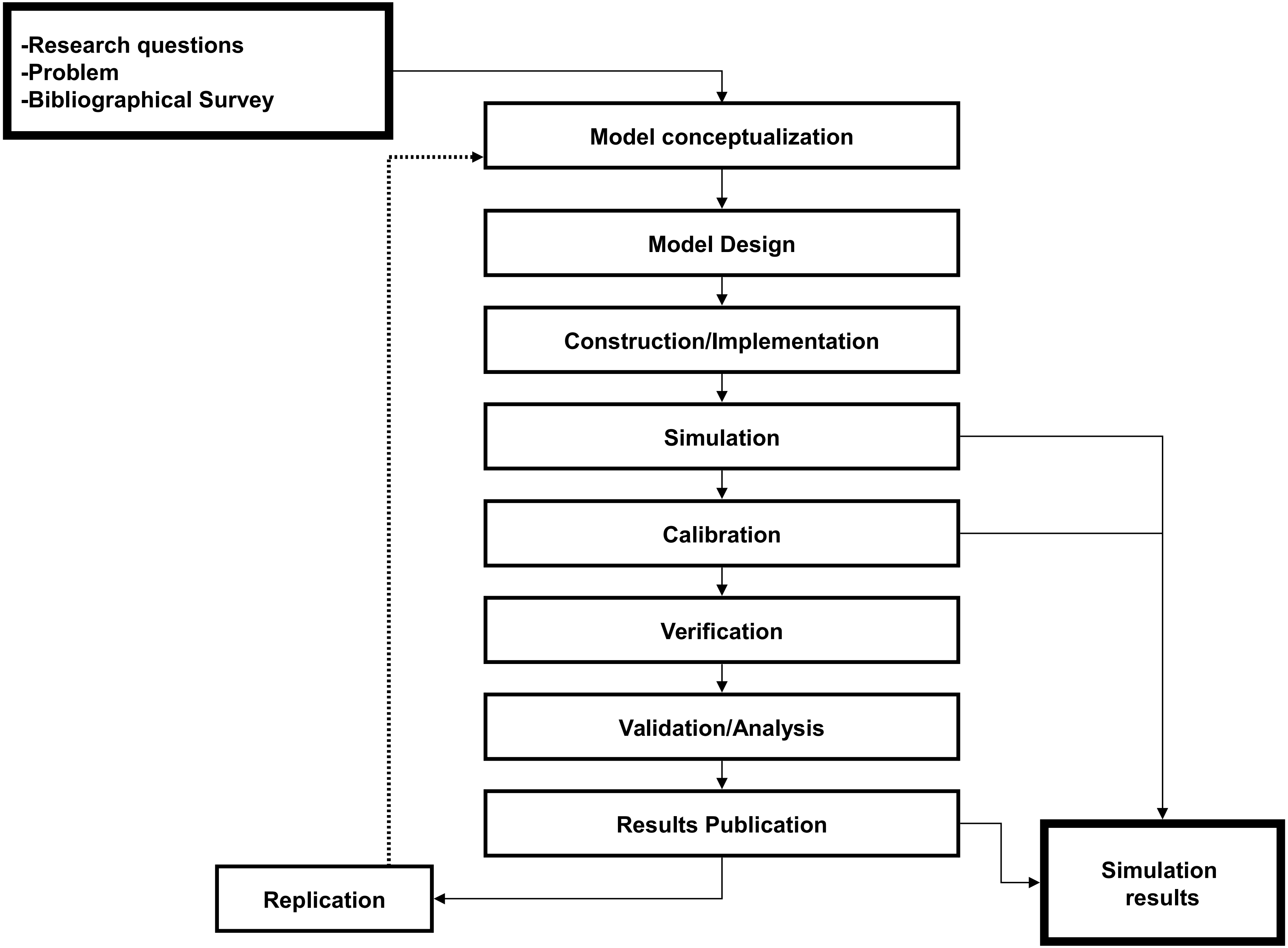
b. **Social impact on mobility: kinship vs. Neighborhoods**
   i. Attraction: alliances
   iii. Repulsion: enemies

c. **Political impact on mobility:**
   i. Attraction forces: leadership
   iv. Repulsion forces: carrying capacity, social conflict

d. **Identity similarity vs. Biological phenotipic similarity: from ethnicity to race**

Recreating the Past in the Computer

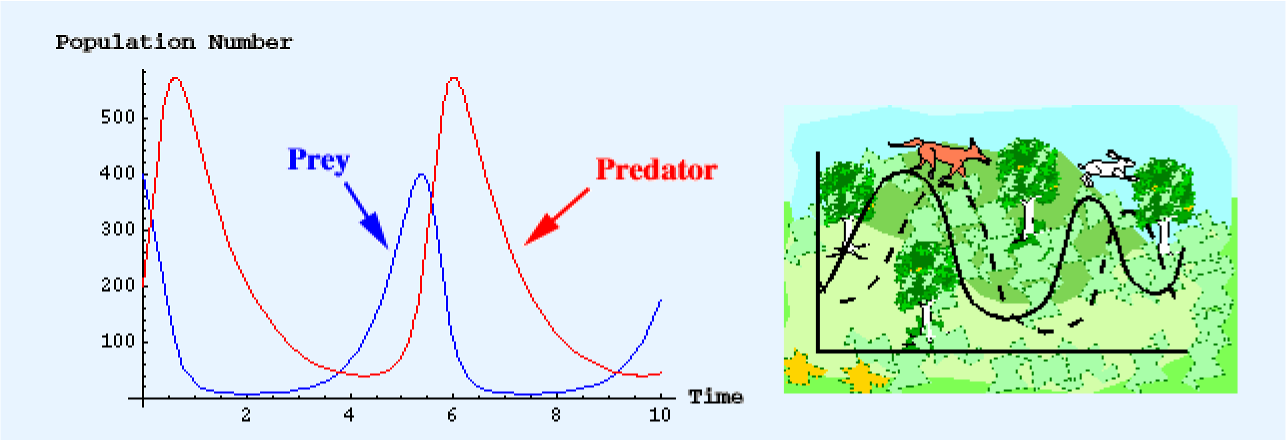
"Would someone please remind me what our origina intention was?"


-Research questions
-Problem
-Bibliographical Survey
Model conceptualization
Model Design
Construction/Implementation
Simulation
Calibration
Verification
Validation/Analysis
Results Publication
Replication
Simulation results

In archaeology, agent-based simulations have been used to

- to test the internal coherence of social theories of human action in the past
- Explaining historical/archaeological data with some hypothesis from ethnographic research.

Simulating animal behavior



Animal behavior is a good example of social mechanism (without abstract beliefs nor complex motivations, nor desires and only simple instinctive intentions), and therefore it has been studied in formal terms since the times of A.J. Lotka (1910) and V. Volterra (1926).

FROM ANIMALITY TO HUMANITY.

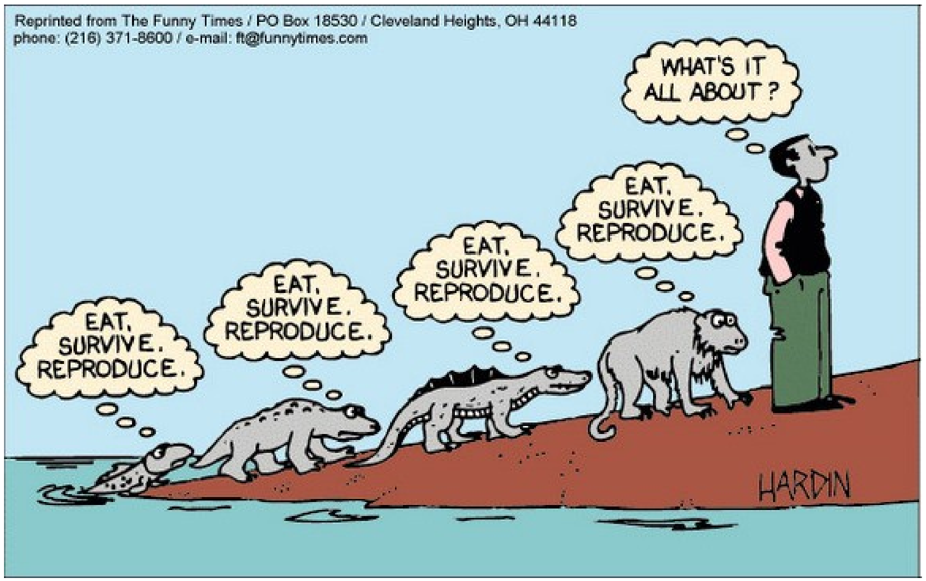
There is a lot of “animality” within us, and if we want to know why we do what we are doing in the present, the only way is to understand our “degree of animality” and the historical process of differentiation from our “original” animality.

In any case, the most important aspect of investigation will not be the animal basis of human behavior, but the specific process of progressive differentiation in the way we take decisions –more or less rational- from the original animal instincts.

FROM ANIMALITY TO HUMANITY.

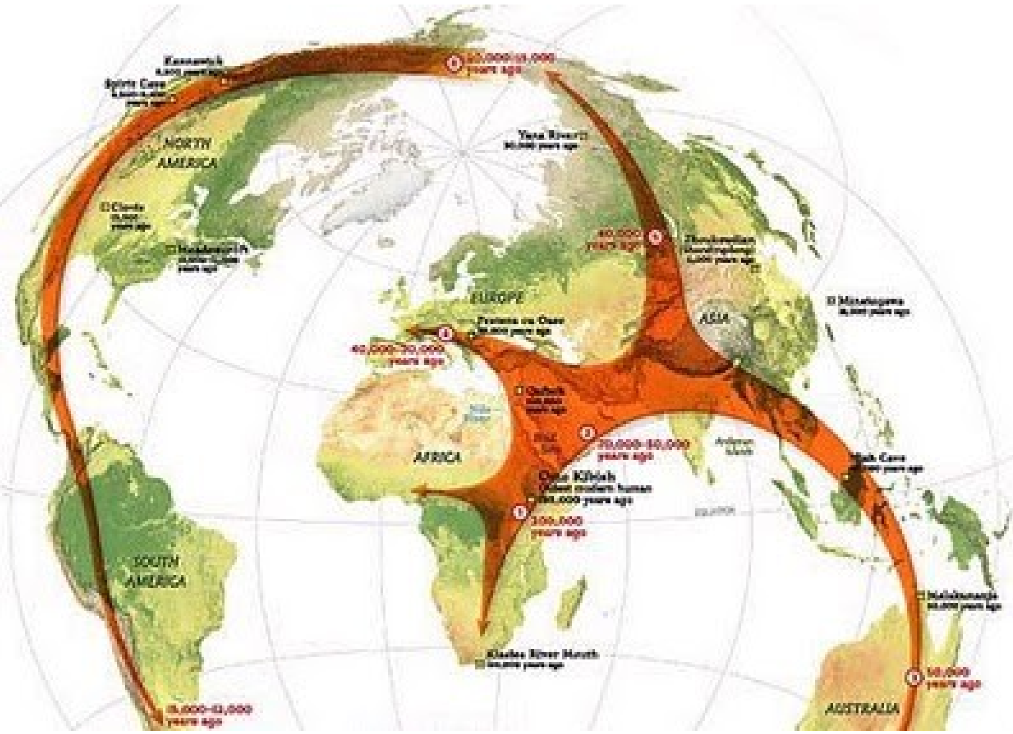
Among recent essays in this direction, we can mention: Arenas (2012), Hoban et al. (2012), Kawecki (2012), Ma et al. (2012), Kutsukake and Innan (2013), Messer (2013), Mode et al. (2013), Villmoare (2013), Schlötterer et al. (2014), Smaldino et al. (2013), Acevedo-Rocha et al. (2014), Hunemann (2014), Lehman and Stanley (2014), Vevgari and Fioley (2014), Roseman et al. (2015), Peart (2015), Shamrani et al. (2015), Smith et al. (2015).

FROM ANIMALITY TO HUMANITY.



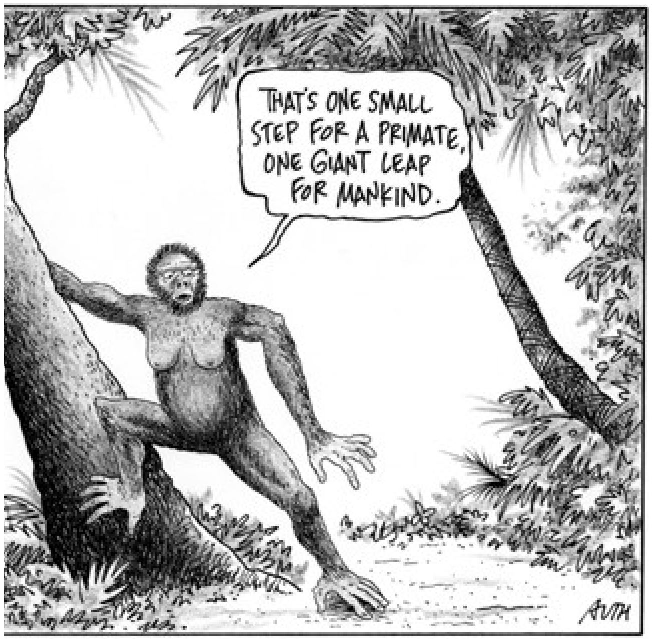
In any case, natural selection and evolutionary mechanisms have affected animals and humans not only in morphology, but in the development of pre-human behavior. It is also the question of the origins of "intelligence" and complex decision making (Gabora and Russon 2011, Gabora and DiPaola 2012, Kurzweil 2012, Chandrasekaran 2013, Pringle 2013, Guddemi 2014, Ross and Richerson 2014, Geary 2015) and also culture. This is not the place to define what is culture, but recent work suggests its computable basis

Out of Africa Hypothesis



The causes, mechanism and Routes of expansion of Homo Erectus have been analysed

OTHER EXAMPLES



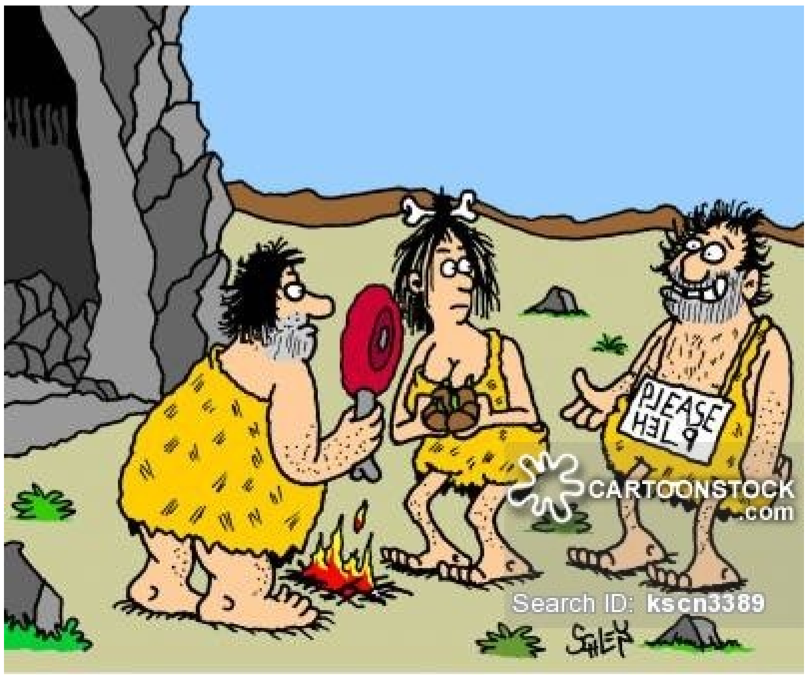
A computer model of wayfinding behaviour for studying hominin dispersals and their chances of longterm
success.

Added complexity comes from considering an agent's wayfinding motivation, strategy, and differential cognitive spatial abilities

Neanderthal Behavior

It can be of interest to compare the dispersal mechanism of pre-humans, to the motivations and intentionality of movement and dispersal by modern humans of “prehistoric” times, with motivations different from modern humans of present times, and even our antecessors from a more recent past with motivations assumed to be like ours

Hunter-Gatherers

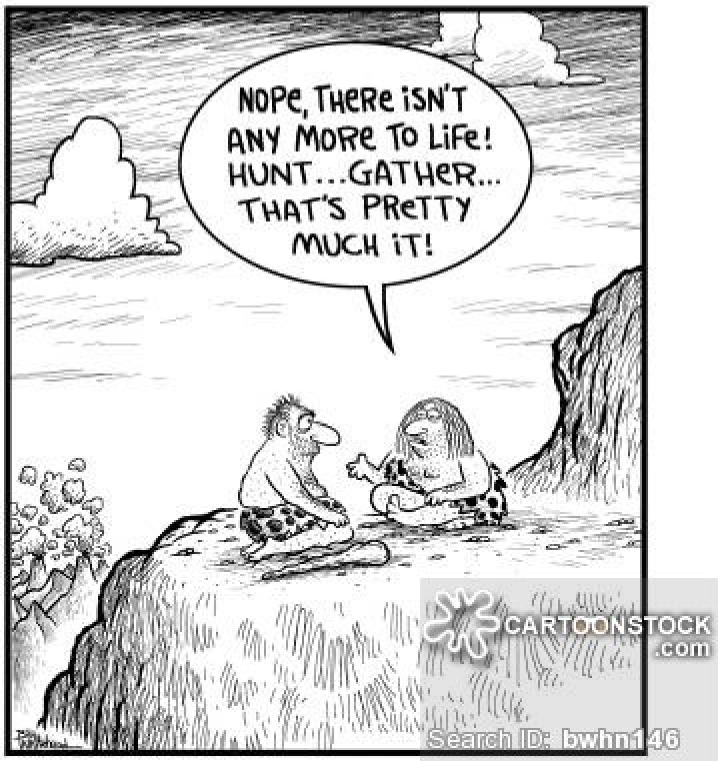


GHAK WAS A HUNTER, ZHOOMBA WAS A GATHERER AND FNOK WAS A SPONGER.

HUNTING-AND-GATHERING IN THE PAST EXPLAINS HOW WE HAVE SURVIVED UNTIL THE PRESENT.

Prehistoric hunter-gatherers have been studied many times from the point of view of animal foraging behavior, stating that human agents also forage in such a way as to maximize their net energy intake per unit time.

Hunter-Gatherers



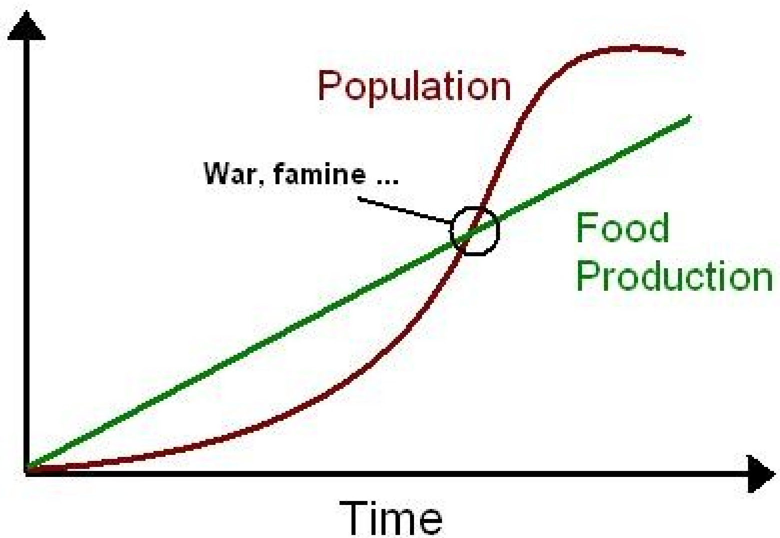
The understanding of many ecological concepts such as adaptation, energy flow and competition hinges on the ability to comprehend what food items such human agents selected, and why. Nevertheless, it is obvious that if humans were in the past just like any other animal forager or predator, we would say that prehistoric hunter-gatherers survival would have depended just on the availability of edible resources. Given what we know about the natural irregularity of natural resources yield, *Homo sapiens* would have extinguished many times since their African origins!

Hunter-Gatherers

The second part of the problem when trying to couple the social and the environmental lies in modeling carrying capacity and the capability of prehistoric humans, even with inefficient technology to alter and modify it.

In the process of truly coupling human activity and natural environment, computer simulation approaches allow understanding how human decisions and subsequent actions would change (at least affect) the structure and function of many natural systems. Such structural and functional changes would in turn exert influence on human decisions and actions

Reformulating Malthus



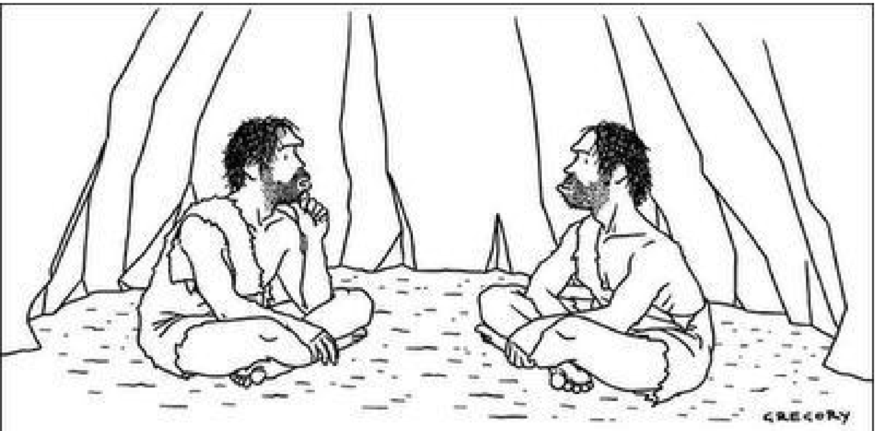
Old Malthusian view on population increasing exponentially while food production would have increased only linearly, in constant increments has been reformulated
within ABM models (Portugali 1999, Read and LeBlanc 2003, Lane 2010, Cai 2012, Schlueter et al. 2012, Levin et al. 2013, Hritonenko and Yatsenko 2013, Ribeiro 2015).

Prehistoric Demography

"We have one hunter and one gatherer... everyone else is a consultant."

The single most obvious constraint of human action in a particular environment is population size, especially when the means of production seem to be underdeveloped (hunting-and-gathering). Many modern computer simulations on human demography are centered on modeling the particular dependence on annual fertility tables and adopt a fecundity based model. The odds of conception for any one mating event can be kept constant for a female agent of a given age, and the probability of reproduction therefore becomes dependent on the frequency and timing of the female agent's mating activity. This allows for realistic fertility variations as a function of mating behavior frequency (and thus contextual opportunity in the form of access to male sexual resources) and the variations of individual agent fecundity over time.

The myth of the stupid prehistoric savages.

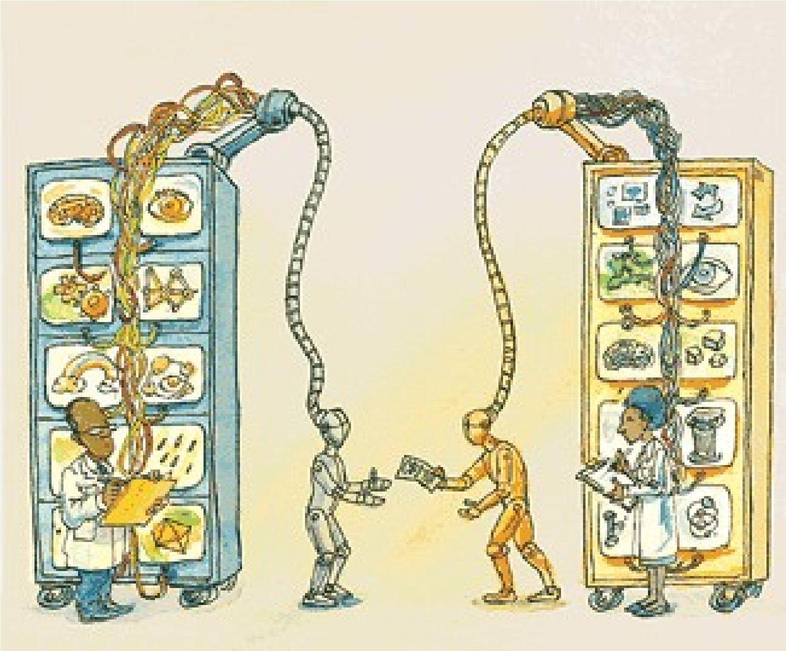


"Something's just not right—our air is clean, our water is pure, we all get plenty of exercise, everything we eat is organic and free-range, and yet nobody lives past thirty."

Socio-ecological models make emphasis on physiological motivation. Intelligence is expressed in the way they look for the satisfaction of their full stomachs. However, if physiological motivation is the only source of directness in the computer simulation of human behavior we may end with undesired, uniform behavior.

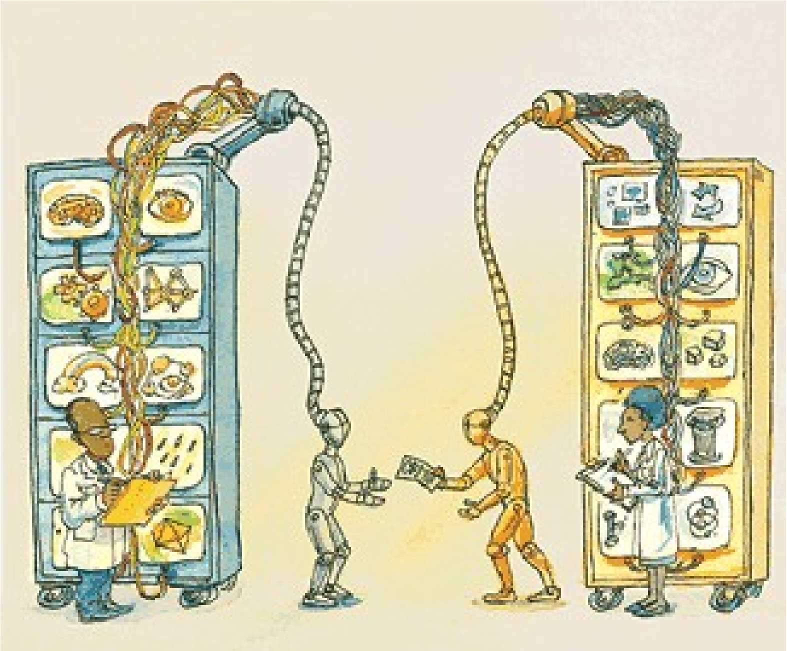
Human (and even animal) rationality is much more complex than expected and therefore, it is easy to conclude that deterministic relationships between environmental stress and social change are inadequate

The myth of the stupid prehistoric savages.



Socially intelligent agents (SIAs) should be defined as agents that do not only from an observer point of view behave socially but that are able to recognize and identify other agents and establish and maintain relationships to other agents (Dautenhahn 1998). The process of building SIAs will always been influenced by what the human as the designer considers “social,” and conversely, agent tools that are behaving socially can influence human conceptions of sociality

The myth of the stupid prehistoric savages.



One of the very first computer simulations of prehistoric hunter gatherers was that of Robert Reynolds (1986). He explicitly approached the problem of rationality in hunter-gatherer decision-making in terms of:

the ability of each member to collect and process information about the resource distribution,

the extent to which information is shared among members,

the specific sets of decision available to each member, and

the way in which the individual decisions are integrated to produce a group decision.

Jim Doran: EOS Model

THE EOS MODEL

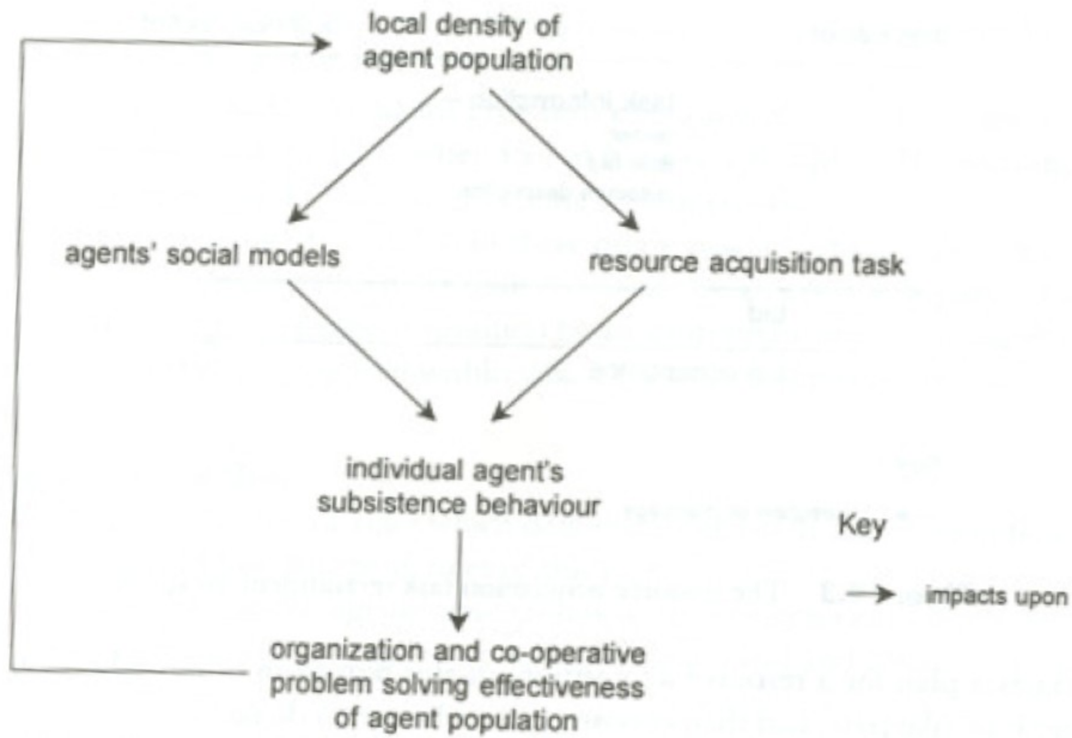


Figure 9.2 The heart of the EOS model. Population concentration impacts upon the characteristics of the environmental resource acquisition task, and both impact on agents' social models. These in turn affect the agents' behaviour and hence community effectiveness, which has an effect on on population density, closing the loop.

THE MYTH OF THE GOOD PREHISTORIC SAVAGE:

The origins of social differentiation and complexity.

An obvious consequence of this way of considering social organization as an emergent property of the mechanisms of cooperation (or the lack of it) and cultural transmission, is that the origins of social diversity, hierarchy and complexity can also be considered as emergent properties of relatively basic social mechanisms.

SIMULATING SOCIAL TRANSITIONS

The Origin of Agriculture

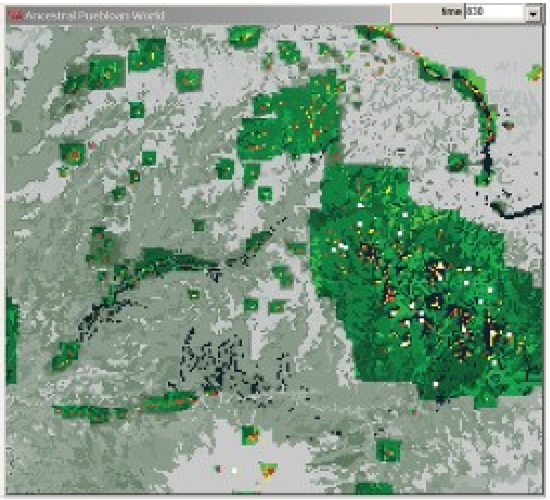
This is the obvious domain for computer simulations. Can agriculture and related practices of animal control emerge "mechanically" in a group of agents originally defined as foragers and predators? The technological side of this transition is not the result of the "intelligence" of some individuals who "invented" something new. As computational simulations have proved domestication of plants and animals is an evolutionary emergent result. Therefore it seems that there are some possibilities that one of the most relevant transitions in the history of humanity had also a mechanical basis.

SIMULATING SOCIAL COMPLEXITY

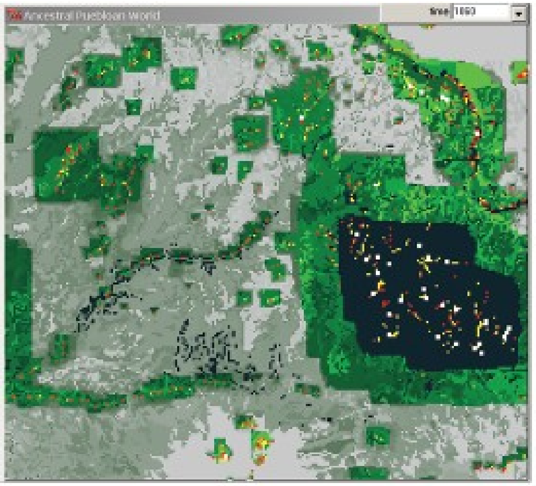
Once human communities begin producing food and exchanging goods, social dynamics become more complex.

There are a lot of examples of ABM models of complex prehistorical societies

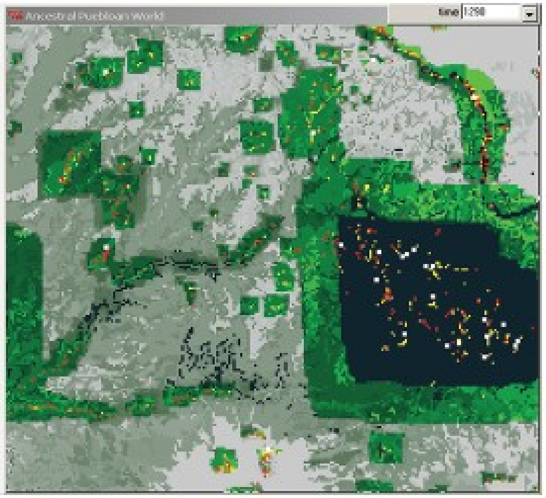
Tim Kohler et al
Village project (2000-2007)



A.D. 830

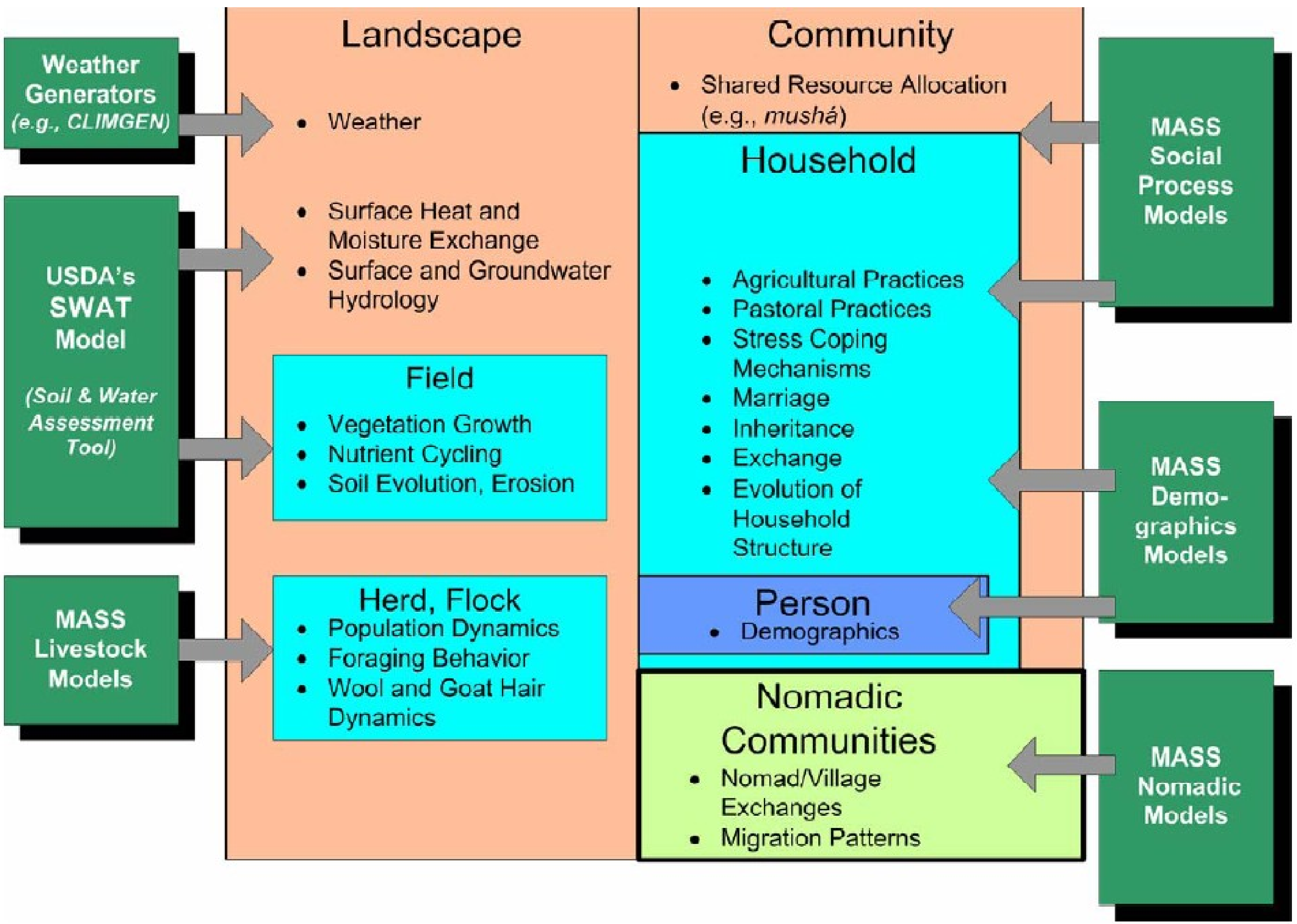


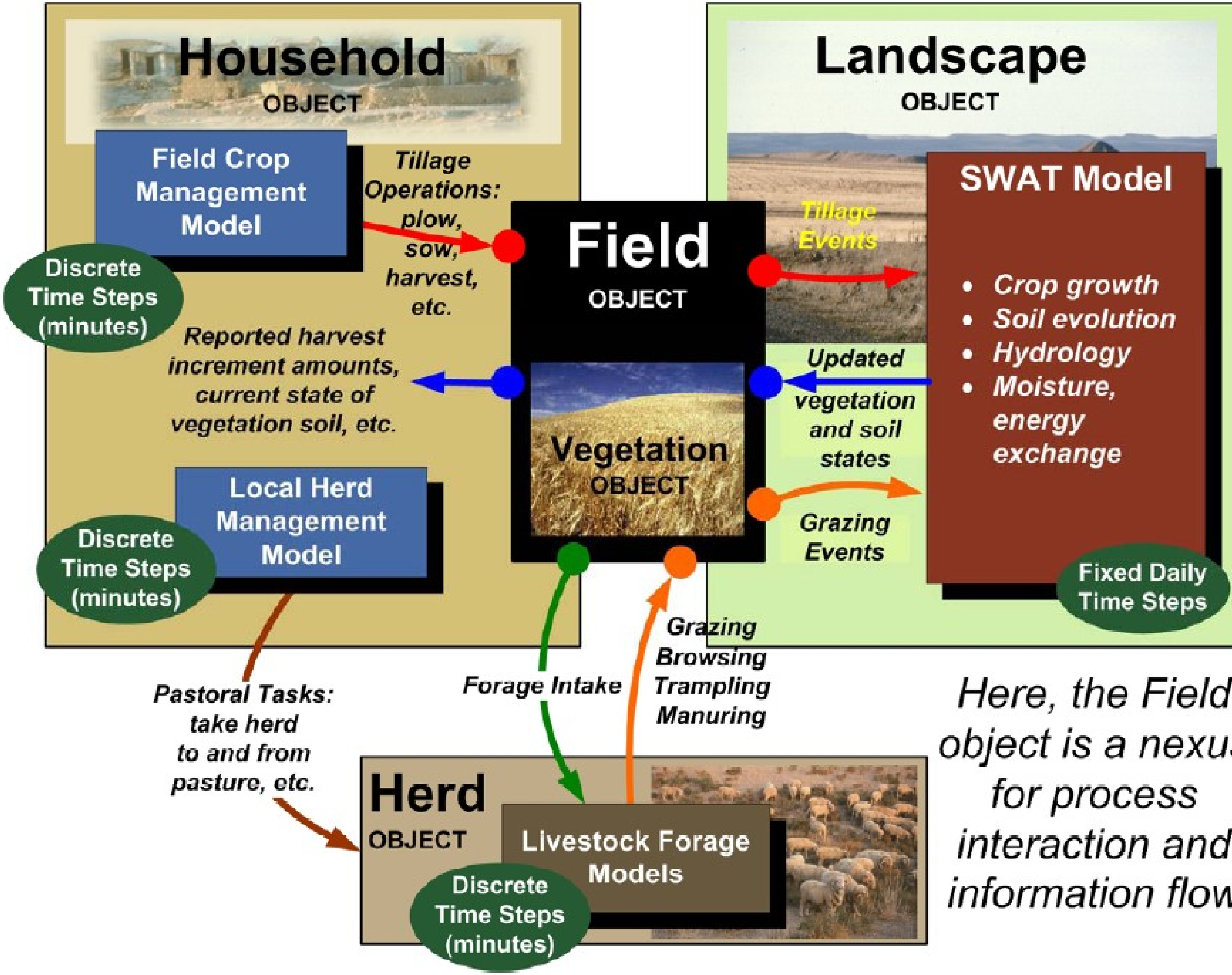
A.D. 1060



A.D. 1290

MESOPOTAMIA





Here, the Field object is a nexus for process interaction and information flow

Different authors have generated computer simulations to understand how hierarchical decision-making could have affected inter-group conflicts sometime through the historical evolution of human society (Mark 1998, Suleiman and Fischer 2000), the dynamics of status symbols in hierarchically ordered societies (Pedone and Conte (2001), the consequences of wealth distribution (Impullitti and Rebmann 2002), the coevolution of farming and private property (Bowles and Choi 2013, Cockburn et al. 2013, Angourakis et al. 2014), the origins of war (Duering and Wahl 2014) and the Neolithic transition from egalitarianism to leadership and despotism (Levine and Modica 2013, Powers and Lehman 2015).

OTHER EXAMPLES

A computer simulation of the Bronze Age salt mines of Hallstatt in Austria (dated to 1458-1245 B.C.)

By employing certain hypotheses arising from excavated archaeological findings (e.g. pick handles, lighting chips, mine
timber) together with additional assumptions and estimated data (e.g. crop, spatial distances, working time), we can develop a
technological reconstruction in form of a mental model.

OTHER EXAMPLES

A computer implementation of mechanisms of population dynamics and carrying capacity of the late Iron Age oppida in Bohemia.

The system dynamics component is used to provide a way to explore and test various general theoretical hypotheses related to the functioning of the settlements and the societal rules that are shaping them,

OTHER EXAMPLES

A model of the the spatial distribution of early Etruscan states within a geographic network structure in order to shed light on how space conditioned their development.

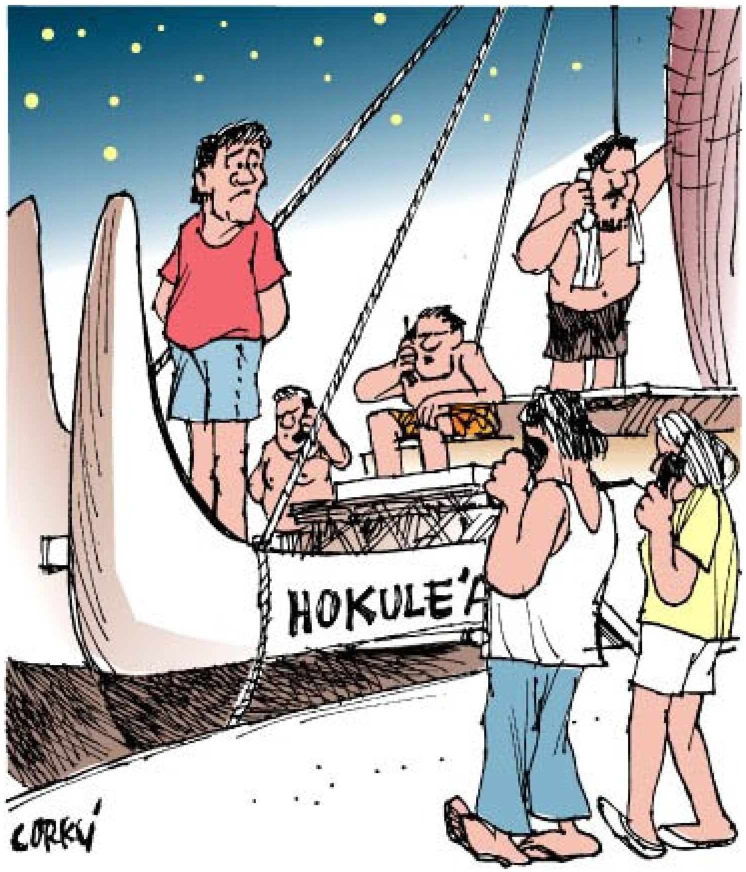
The relative spatial interactions amongst the sites in the study area has been simulated using an agentbased model, a radiation analogy model, and a Hamiltonian gravitational model.

OTHER EXAMPLES

A computational model of hypothetical trade mechanisms in the Roman East.

The Roman Bazaar is based on the idea that markets in the Roman Empire were very weakly integrated and largely driven by the particular commercial opportunities of agents in the many trading places around the Empire. These opportunities were structured by the agents' social networks, leading to a relative unpredictability of supply and demand, high uncertainty of information, and many irregularities in prices and available products.

OTHER EXAMPLES



A computer model of the settlement process of Oceania based upon the simulation of trajectories of different types of canoes sailing through different wind patterns throughout Oceania to suggest that there were two "schools of navigation", one to the east and another to the west of Samoa.

OTHER EXAMPLES

Gavrilets et al. (2014) have developed a spatially explicit agent-based theoretical model of the emergence of early complex polities via warfare. In this model polities are represented as hierarchically structured networks of villages whose size, power, and complexity change as a result of conquest, secession, internal reorganization (via promotion and linearization), and resource dynamics.

OTHER EXAMPLES

A possible criticism about the idea of simulating the past would be the impossibility of simulating the historical evolution of complex polities in modern times for reasons of scale: to be fully capable of understanding historical dynamics of ancient empires and modern nations we would need to create artificial societies of such complexity that any computer could run the simulation. Nevertheless, the current use of agent-base modeling and related techniques to understand modern economics and modern social and political organization clearly indicates the opposite..

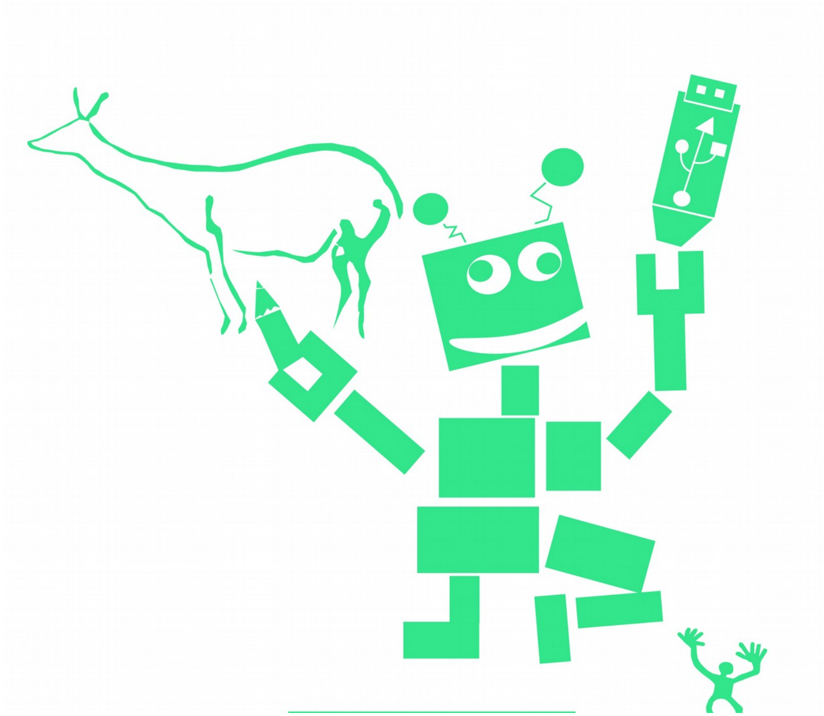
¿Podemos “predecir” el Pasado?

PROBLEMAS

Possible Criticisms

Are we LEARNING something about the past
or just playing with the results of our historical imagination?

Possible Criticisms



We have to investigate
The proper relationship between:
- Historical hypothesis
- Social mechanism
- Archaeological data

Possible Criticisms

In that sense,
A social mechanism without
Temporal dynamics has not meaning
For a scientific archaeology

Possible Criticisms

But Temporal dynamics
Can only be defined on
The basis of well dated
Historical-archaeological
data

Remember…..

we may study a subset of social activity:

collective action,

The negative side of this approach is that there is no possibility of knowing why an individual person made something somewhere at some moment. However, it does not presuppose the implicit randomness, subjectivity, or indeterminism of social action.

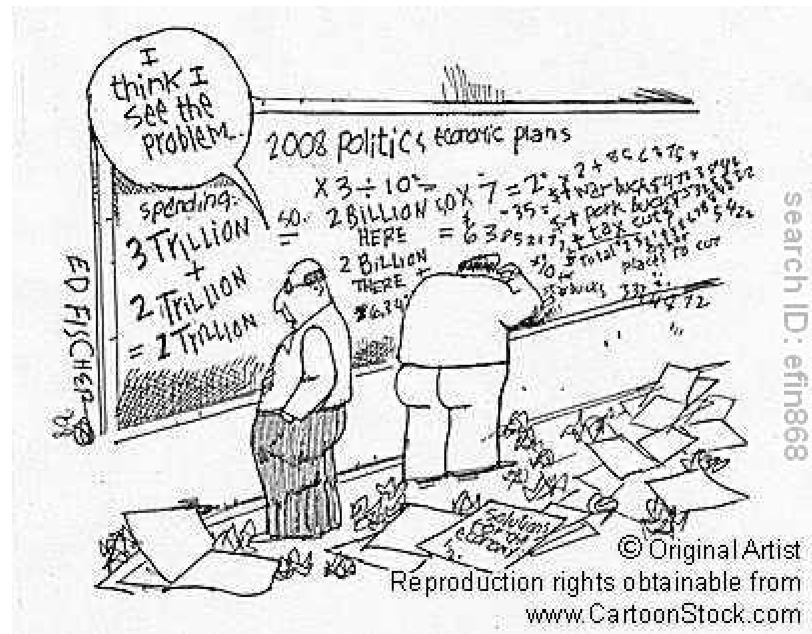
The goal should be to explain the sources or causes of that variability, and not exactly the inner *intentions* of individual action.

Social mechanisms

It is not complexity in itself what should interest us.

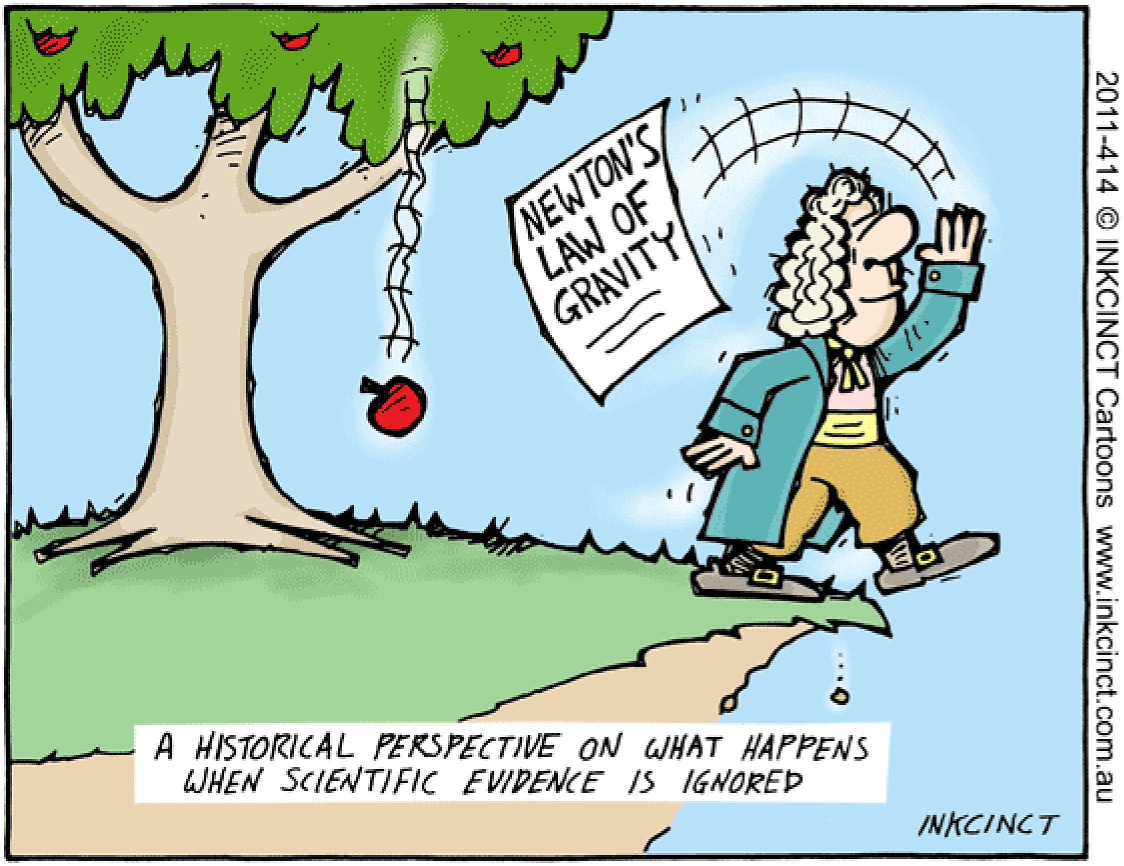
A social mechanism is not “better” than other because it is more complex,

But it is its explanantory capability



EXPLANANTION

… and "explanatory" is not a universal property of any system. It is always relative to concrete circumstances, to particular data sets



Prediction

"I REMEMBER WHEN TEA LEAVES WERE THE STATE-OF-THE-ART METHOD OF FORECASTING."

Computer simulation of the past
Can be seen as a reivindication for historical prediction.

If we feed a computer with data from the past, can we predict the future?

Prediction

The answer is…..


"Oh, not a computer, Barceló — we're replacing you with a computer *simulation*."